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Environmental Protection Agency

Prepared for:

Alan M. Voorhees and Associates, Incorporated

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This report has been prepared to assist state and local air pollution control agencies in utilizing land use and transportation plans in preparing Air Quality Maintenance Plans. An overview of general methods and practice in land use and transportation planning describes and discusses the development and uses of comprehensive plans and 3-C plans. General approaches are offered for considering air quality maintenance in the comprehensive planning process and for evaluating impacts of land use and air quality plans and policies. Information, organization and analytical technique necessary for relating land use and transportation to air quality are discussed. Appendices include a review of the state-of-the art for quantifying the relationship of land use and transportation plans to air quality, a review of studies relating land use and transportation to air quality, and an annotated bibliography of activity allocation procedures.

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VOLUME 4:
LAND USE AND TRANSPORTATION CONSIDERATIONS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
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FOREWORD

This document is the fourth in a series comprising Guidelines for Air Quality Maintenance Planning and Analysis. The intent of the series is to provide State and local agencies with information and guidance for the preparation of Air Quality Maintenance Plans required under 40 CFR 51. The volumes in this series are:

Volume 1: Designation of Air Quality Maintenance Areas
Volume 2: Plan Preparation
Volume 3: Control Strategies
Volume 4: Land Use and Transportation Considerations
Volume 5: Case Studies in Plan Development
Volume 6: Overview of Air Quality Maintenance Area Analysis
Volume 7: Projecting County Emissions
Volume 8: Computer-Assisted Area Source Emissions Gridding Procedure
Volume 9: Evaluating Indirect Sources
Volume 10: Reviewing New Stationary Sources
Volume 11: Air Quality Monitoring and Data Analysis
Volume 12: Applying Atmospheric Simulation Models to Air Quality Maintenance Areas

Additional volumes may be issued.

All references to 40 CFR Part 51 in this document are to the regulations as amended through July 1974.

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CHAPTER I

INTRODUCTION

A. REQUIREMENT FOR AIR QUALITY MAINTENANCE PLAN PREPARATION AND ANALYSIS

The 1970 Clean Air Act (as amended) has mandated all states to identify areas that are in violation of the National Ambient Air Quality Standards (NAAQS). These standards, as set forth by the U.S. Environmental Protection Agency (EPA), prescribe the control of sulfur oxides (SO_x), particulate matter (TSP), carbon monoxide (CO), hydrocarbons (HC), nitrogen dioxide (NO_2), and photochemical oxidants. This is to be accomplished by the State Implementation Plan (SIP). In addition, all states, pursuant to 40 CFR 51.12(c), are required to identify areas that have the potential to be in violation of any NAAQS over the 10-year period, 1975-1985. These areas are called Air Quality Maintenance Areas (AQMA), identified by the states, and reviewed by the EPA Administrator, who issues an official list of designated AQMAs.

For these areas, the states must submit plans to prevent any national standard from being exceeded over the 10-year period. For each pollutant in each of the AQMAs for which analysis indicates a potential problem, tailored maintenance strategies must be submitted. These plans, Air Quality Maintenance Plans (AQMP), must be prepared, adopted, and submitted in compliance with guidelines issued by EPA. Considerations such as terrain, meteorological conditions, transportation and land use planning, and economic considerations can be incorporated into the AQMP.

B. REPORT ORGANIZATION

Chapter II of this report presents an overview of land use and transportation planning. The comprehensive plan and the 3-C process are described. This discussion is intended to provide air quality planners with a brief review of the comprehensive planning process and its implications for air quality maintenance planning.

Chapter III presents a general approach for considering air quality maintenance in the comprehensive planning process. A procedure for analyzing the impact of land use and transportation plans or policies is described. This analytical procedure would provide a basis for review and evaluation. The analytical procedure may require the development of techniques to relate land use to air quality. These analytical requirements are discussed.

Appendix A is a review of the state-of-the-art in quantifying the relationship between land use and air quality.

Appendix B summarizes selected studies that were reviewed in the preparation of the state-of-the-art review.

Appendix C is an annotated bibliography of activity allocation procedures that may be useful in the development of analysis procedures for incorporating air quality maintenance into comprehensive planning.

CHAPTER II

OVERVIEW OF LAND USE AND TRANSPORTATION PLANNING

A. THE COMPREHENSIVE PLAN

The land use plan, as a document, exists within the broader framework of the comprehensive plan (sometimes called the master plan). "It (the comprehensive plan) indicates in a general way how the citizenry of a jurisdiction, represented by its leaders, wants its community to develop physically over the next 20 to 30 years."* In this context, the word "comprehensive" generally means that the developed plan encompasses all geographic parts of the community and all functional elements that bear on physical development. In the past, the emphasis on physical development has often excluded considerations of the environment, resulting in the generation of harmful impacts. A redefinition of the comprehensive planning process, which seeks a more balanced approach to the consideration of economic, social, and environmental variables, is a recent factor in the planning process. At the present time, several agencies, including EPA and the Department of Housing and Urban Development (HUD), are developing procedures to reflect this expanded concept. These are in the initial stages, and no material is available for reference.

The comprehensive plan as a policy statement presents development proposals for both public and private land within the planning area. The comprehensive plan as a schematic map presents the spatial allocations and location of various land use categories plus transportation and community facilities. Although there is no rigid format for the plan, the elements included have tended to become standardized. The following is a generalized sequence of the information included:

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* Alan Black, "The Comprehensive Plan," Principles and Practice of Urban Planning, edited by William I. Goodman and Eric C. Freund (Washington, D.C.: ICMA, 1968), p. 349.

- Background information - This phase of the planning process is directed toward data collection and data processing. Key considerations are studies of the urban economy, employment, population, activity systems, and urban land. Such studies are a prerequisite to the task of determining future land use requirements and the subsequent land use planning proposals. Planning studies also deal with the physical opportunities and constraints imposed by flood plains, soils and geologic conditions, topography, and climate. This element typically includes land use objectives and goals that provide a guide to the way in which development should proceed to fulfill the needs of residents, firms, and institutions of the area.

- Functional plans - This series of specific land use and facilities plans forms the body of the document. The plans generally include sections on residential, commercial, and industrial areas; recreational and community facilities; public utilities; and transportation.

- The comprehensive plan - The final product is a synthesis of the functional plans, providing an explanation of how various major functions are tied together by thoroughfares and developed in balanced relationship to one another. An important element of the comprehensive plan is the means by which it is to be implemented. A program to implement the plan is concerned with such regulatory measures as zoning, subdivision control, and housing and building codes. A public works program also may be included.

In spite of the fact that the elements included in the plan are fairly standard, there is a wide variation in the level of detail. This variation is due in large part to the strong motivation by the Federal government for the development of comprehensive plans at various jurisdictional levels, from local to regional and state.

Although comprehensive planning has existed as a concept for over 50 years, it only began to move to the forefront of local planning agency concerns after World War II. The impetus was the Federal government's increasing tendency to make financial assistance conditional upon conformance to a local comprehensive plan. This requirement has been supplemented by Federal funds to be used for the purpose of preparing these plans. Two of the chief sources of this type of Federal planning grant have been Section 701 of the Housing Act of 1954, as amended, (the "701 Program") and the transportation planning grants under the Federal-aid Highway Act of 1962 (the 3-C Process). The 701 planning grants were made under this program to established state or local planning units that applied for them. Under these grants, the primary concern was with housing, transportation, or general land use. However, whatever the primary focus, planning was generally integrated to some extent into the total urban scene. In spite of these programs, not every area has a comprehensive plan or the more basic land use plan.

A basic component of the comprehensive plan is a document, or series of documents, known collectively as the land use plan. This plan is primarily concerned with the geographic allocation and amount of land development required for the various space-using functions of urban and suburban life--industry, business, housing, recreation, education, and the religious and cultural activities of the people. Therefore, the land use plan has a great influence on the other functional areas included in the comprehensive plan, such as transportation, public facilities, and public utilities. For this reason, this part of the comprehensive plan provides a direct link between planning and environmental quality.

Some planning agencies, because of legislative definition or common usage, refer to the land use plan as that portion of the comprehensive plan devoted to private uses of land--industrial, commercial, and residential. In other areas, both public (community facilities) and private uses are considered to be a part of the land use plan. The land use plan should not be confused with the zoning map or the zoning ordinance. The land use plan is not legally binding; hence, it is essential that the necessary legislation be prepared, adopted, and enforced to transform the general concepts into patterns that have legal substance.

Zoning is one of the several legal devices for implementing the proposals for land development set forth in the plan. The zoning map is a part of the zoning ordinance and is generally conceived as a scheme of districting an area for purposes such as land use regulation, population density, lot coverage, bulk of structures, and parking requirements. Both the zoning ordinance and the zoning map may be more detailed than the land use plan.

The process for developing a land use plan is not fixed; therefore, the procedure described in this section is generalized. The format and procedures presented here have been adapted from the work of F. Stuart Chapin., which presents a more detailed discussion of these topics.* It should be stressed that the analytical procedures presented in this section do not represent a definitive listing; rather, they represent the approaches most commonly used by planning agencies at different levels.

The traditional approach to land use planning begins with a projection of future economic growth in the area. This projection is based on trends in both the national and the regional economy. Given the projection, in terms of the amount and type of economic activity translated into employment levels, future population is projected. Projections of economic activity and population are then translated in turn into projections for future land demand for industrial, commercial, residential, and public activities. This represents the demand side of the process, which must be matched against the supply of land. Land supply is evaluated according to availability (vacant or unused land) as well as to the available land's suitability and capacity for the various proposed activities. Availability is determined through an inventory of existing land use.

The suitability and capacity of a parcel is defined in terms of accessibility, size, and general physical quality. Quality denotes environmental characteristics to a varying degree. "Generally, consideration is given to a parcel's buildability, considering soil and slope conditions. The basic assumption of this approach is that economic growth will bring positive benefits to the community and that such growth can best be fostered by designing the land use pattern to maximize accessibility within the system of economic activity."*

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* F. Stuart Chapin, Urban Land Use Planning (Urbana, Illinois: University of Illinois Press, 1965).

This approach to land use from a purely economic point of view has been coming under increasing scrutiny because of increasing sensitivity to environmental effects. Future land use planning procedures will evaluate the suitability of land for certain uses from the point of view of cost to the developer, from the perspective of land as a resource to be protected from misuse, and from the perspective of potential environmental impacts of its development.

This process results in a document that is the basic element of the comprehensive plan. It is generally presented toward the end of the report as a composite of those functional plans for specialized types of land use. The generalized land use plan for the area usually does not show individual detailed parcel uses. The land use areas are broad, and the boundaries are sometimes imprecise. For the exact location of facilities or parcel uses proposed, sector or neighborhood development plans should be reviewed.

In a very few large urban areas, e.g., Baltimore, Dallas-Ft. Worth, and San Diego, the land use and land activity patterns have been quantified for a computerized land use/land activity model. This procedure permits evaluation and projection of land activity over time; however, at present, it is not readily available in most urban areas and consequently is not discussed in this chapter. Detailed discussion of the land use models may be found in Appendix C, and the application of such models may be found in Appendices A and B.

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* Edward J. Kaiser, et al., "Land Use Planning: The Cornerstone of Local Environmental Planning and Control," Land Use and Environment, edited by Virginia Curtis (Washington, D.C.: EPA, 1972), p. 104.

The following sections discuss the land use plan in greater detail to provide the evaluator with the necessary information to use the plan in the determination of the air quality for an area. Particular attention is given to the preliminary studies that form the basis for the plan as well as the data that they provide, which may have applicability for air quality analysis.

1. The Land Use Plan

The land use plan, as a pattern for existing and proposed activities, provides a map of potential patterns of emissions. For the purposes of air quality modeling, one way of looking at sources of pollution is to place them in one of the following categories:

- Point Source - A single major emitter located at a point. A similar type of source is that designated as "stationary."
- Line Source - A major highway link or other transportation link denoted by its end points. This source is also occasionally referred to as a "mobile" source to differentiate it from "stationary" above.
- Area Source - An aggregation of smaller, less specific sources that are spatially distributed over an area. This includes residential emitters, single emitters, and highway links deemed too small to be considered as individual point or line sources by the model. The boundaries of the area are not fixed. They may or may not coincide with those of political jurisdictions. The total area may be partitioned into squares and referenced to some type of grid coordinate system if this is the form the model requires.

The degree to which public facilities and major transportation facilities are detailed on the land use plan may vary considerably from agency to agency. Proposed public land uses may be shown on the public facilities plan or land use plan; hence, those will provide a basis for part of the air quality analysis. In order to consider major transportation sources of pollution, the transportation element of the comprehensive plan or the 3-C transportation plan (see Part B of this chapter) can be used as a base.

The information used in the calculated demand for a particular land use can be used in the projection of air pollution emissions as discussed below. In addition, the supplementary information presented in each functional plan is evaluated for its utility in air quality projections.

In general, the minimum information produced through the studies done prior to the development of the land use plan includes:

- Current and Projected Urban Population - These studies are concerned with the total and future population size, as well as its composition in terms of such qualitative considerations as age groups, household sizes, and income composition.
- Current and Projected Urban Area Employment - Employment is measured by major SIC (Standard Industrial Classification) categories or grouped under broad employment activities such as manufacturing, wholesale, and office-related.
- Existing Land Use - Land use data is summarized both statistically and in map form according to ground use categories such as residential, commercial, and industrial.
- Housing - The current stock of housing is summarized by type of structure.
- Vacant and Renewal Land - A map showing vacant areas, as well as a tabular summary, indicates the general suitability of parcels for development.

The specific types of studies often preferred to determine the allocation of land include economic, employment, population, activity, and urban land. These studies are examined briefly below, with each discussion describing the types of methodologies that can be used to obtain the relevant statistic. This is then evaluated for its utility in projecting air quality.

a. Urban Economy - "The destiny of an urban center is controlled by the extent and character of its productive or income-producing activities and their general vitality. Studies of the economic basis of these activities hold the key to how the city has developed, where it is today, and what its future prospects are."* Viewed in this way, the economy conditions the amount of development that occurs, and, hence, influences land use projections. With a knowledge of the trends in the economy, the planner is better able to develop yardsticks that can be used in estimating land requirements. "As an example, studies of employment are a key element in population forecasts, and population estimates are, in turn, used for scaling land development needs. Estimates of future land requirements for industrial uses are based on manufacturing employment trends, and future space needs for commercial uses draw upon employment trends in wholesale trade, etc. Finally, plans for various sizes of shopping centers draw upon studies of population and purchasing power in and around the urban center."**

Two standard approaches to economic projections are the regionally oriented and the urban centered. Whichever approach is taken, the results are a set of statistics showing the projected growth for various types of industry in the area. These are then used as a base for other types of projections.

Regional orientation - The underlying assumption of this approach is that economic activity in the urban center is affected by other centers of economic activity in its immediate region and is ultimately linked to the national economy as a whole. Hence, a city's future economic position is dependent on its capacity to develop new productive resources and to expand existing ones in relation to other cities in the region engaging in the same activities.

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* Chapin, Op. Cit., p. 107.

** Ibid., p. 107.

Presented below are three approaches to the study of regional spheres of influence:

- Input-Output Analysis - This approach is concerned with the dynamics or commodity flows among aggregates of industry. These aggregates (focal points) can be single urban centers or a whole metropolitan complex of centers.
- Regional Accounts System - This is designed to analyze all forms of income-producing activity.
- Approximation Analysis - Using conventional divisions of the nation into regions, subregions, etc., and by crude step-down procedures from the larger parent area, gross measures are developed of how the parts of the whole are estimated to share in total national productive activity.

Urban-centered - The assumption that the analysis begins in the urban area but at the same time is extremely focused in that it seeks to explain the city's economic structure in terms of the goods and services that it produces that are consumed outside of the localized area of study. It identifies it as the "base of the urban economy the goods and services that are consumed externally."*

The primary urban-centered approach to the calculation of economic growth is the economic base, which has received rather extensive applications in city planning analyses. Base theory considers the structure of the urban economy as made up of two broad classes of economic efforts--(1) the basic activities which produce and distribute goods and services for export to firms and individuals outside a defined localized economic area, and (2) the service or nonbasic activities whose goods and services are consumed at home. The concept holds that growth in the basic sector usually means growth in service activities and, thus, growth in total economy.

A local economic base is the preferred method of determining which proportion of current employment is engaged in activities that produce for export, and which proportion is engaged in activities producing for local consumption.

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* Chapin, Op. Cit., pp. 108-109.

b. Employment Studies - Employment forcasts serve two functions in the land use planning process: (1) they provide information of concern to population studies which, in turn, are used in estimating space needs for residential areas, shopping centers, and community facilities; and (2) they supply a direct yardstick for use in determining the land requirements for industrial and non-retail commercial areas.

In industrial areas, space requirements are estimated on the basis of adopted industrial density standards, i.e., manufacturing workers per acre of industrially used land or standards of a more detailed nature based on floor area, shift size, and structural density. In wholesale areas, space requirements are derived from various floor area standards of employees per square foot of building space. Office space requirements are developed on the basis of floor area standards relating employment to space taken up by the category of use.

Various sources of employment statistics are available for use in projecting future employment. The U.S. Bureau of the Census provides statistics on total labor force, civilian labor force, total employment, and manufacturing employment.

There are various methods of projecting employment; several commonly used methodologies are described below.

Input-Output Analysis - Using the estimates of the effective demand for all the various economic lines in the study area for a particular year and estimates of labor productivity for all industries and for the subcategories of manufacturing, finance, insurance, and real estate as given, the actual employment projections are obtained by dividing values of estimated future output by the appropriate values for output per worker. The method, however, presents a great many problems, particularly with regard to the availability of data in the form needed to undertake the analysis.

Income Statistics - The income approach is an alternative to the use of dollar measures of transactions between industries and worker productivity (as the components of the ratio for deriving employment). It utilizes a broader, more inclusive accounting system involving income and product statistics. In this instance, concern is with all forms of income-producing activity, investment, and trade, as well as industrial production.

Apportionment and Ratio Methods - These procedures use employment statistics directly without involving projections of total ouput and output per worker. Although these methods both use step-down procedures in identifying the study area's share of a larger geographic area, the first method accomplishes the step-down by an apportionment technique; the other utilizes direct step-down, omitting the proration analysis of all parts of the whole.

c. Population Studies - To be useful, growth potential must be expressed in terms of the population it can be expected to sustain in terms of the size of the population, its composition and characteristics, and its spatial distribution. Population size provides an estimate of space requirements for various land use categories. Investigations into population composition assist in estimating residential space requirements for various types of dwelling units consistent with family size, income level, etc. They also assist in determining the amount of space needed for recreation areas, schools, and other community facilities. The examination of residential population distribution spatially provides a basis for the location of the various facilities.

Sound demographic analysis is predicated on accurate population data, which includes public census enumerations, unpublished census data, and vital statistics.

To be useful in planning studies, this data has to be used in (1) estimating current population and (2) projecting future population in the study area.

Estimates of Current Population - One of the first studies to be accomplished is the estimate of the current population. Up-to-date population estimates are so vital to all types of planning work that many agencies develop new estimates annually. The most common forms of these methods are summarized below:

- Migration and Natural Increase - This procedure, used extensively by state agencies, is one of adjusting the last census figures of the locale of interest to reflect changes that have occurred to date, considering the effects of migration and natural increase separately.
- Censal Ratio Methods - These are used by both state and city agencies and include any method utilizing ratio procedures. The simplest form of the ratio procedure makes a direct step-down from Bureau of the Census state population estimates to one particular county or SMSA without examining trends in other counties. This should be used, however, with caution.
- Methods Based on Symptomatic Data - These methods, widely used by city planning agencies, derive estimates of the current population by reference to observed trends in data series that are found to have a close relationship to population change and for which current data are available. The vital statistics used include school enrollments, electric meter, water meter, or telephone installations and registered voters.

Population Projections - Perhaps the single most important population study for planning purposes is population projecting. The following lists some of the most common projection methods used in small area studies:

- The Cohort Survival (or Cohort Component) Method - This rather complex method requires an experienced population analyst to execute the projection. The method adjusts figures from the last census forward by age and sex groups (cohorts) year by year to the projection date, with separate adjustments made for each of the three major components of population change: death, birth, and net migration.

- Migration and Natural Increase Method - This method starts with a current estimate of the population, and by introducing adjustments first for migration and then for natural increase on a year-by-year basis, it develops annual estimates into the future until the projection date is reached.

- Apportionment and Ratio Methods - These approaches employ a previously prepared projection for some larger geographic area and, by step-down procedures similar to those for employment projections using this methodology, establish how the local area may be expected to share in the projected population of the larger area.

- Employment Method - Where employment forecasts have previously been prepared for the study area, this method is often used as a basis for making population projections. Using ratios, the method expands future employment figures to labor force estimates, and these are then expanded to population equivalents.

- Mathematical and Graphical Extrapolation Methods - This includes arithmetic and geometric projections, trend extrapolation by the method of least squares, and estimates based on the logistic curve.

Population Distribution- Projections of the distribution of future total population among the various neighborhoods have obvious implications for the study of residential areas and their community facilities. The distribution of population is commonly based upon (1) an analysis of daytime population distribution, and (2) residential distribution.

d. Urban Activity Systems - This type of analysis is not yet a standard part of the land use planning process. Traditionally, planning agencies have gone into land use studies looking at the effects of activity systems rather than seeking to define and understand activities themselves as producers of land use patterns. It should be recognized that there are no fully tested techniques of analysis for this component.

One method in existence is the origin and destination survey done in transportation planning. In the survey, the respondent is asked to identify major activities of various members of the household during the preceding 24-hour period, or he may keep a diary over a longer time frame. The object of the survey is to be able to to identify specific recurrent behavior patterns that will then enable the planner to make analyses of space use and travel in order to develop an integrated set of proposals for land use and transportation for the comprehensive plan.

e. Urban Land Studies - These studies focus on an investigation of the features of the land itself. The information obtained describes the uses for which a particular parcel of land is most suited from a physical perspective. This information often indicates constraints on a particular type of use that could potentially be located on a parcel. It also provides an indication of how the population is distributed throughout the study area. Specific types of studies that would provide this type of information include compilation of data on physiographic features, existing land use surveys, vacant land surveys, hydrological and flood potential studies, and studies of aesthetic features.

For reference, the following types of maps may be used: aerial photographs, engineering maps, topographic and soils maps, and property tax maps.

2. The Utility of the Land Use Plan

A wide variety of information goes into the development of a land use plan. The question then is whether these sources are useful in projecting air quality for the area covered by the plan.

The basic method for the prediction of future air pollution concentration levels expected from the implementation of a land use plan is through the use of an atmospheric dispersion model. Models of this type translate data on emission patterns into patterns of expected concentrations for given time frames. In addition to emissions data, dispersion models require meteorological and topograhic data in order to make estimates of concentration patterns. Also, local air quality measurements are needed to evaluate and refine model performance and to specify confidence limits for the model results.

As mentioned in the introductory portion of the land use discussion, one way of approaching the calculation and projection of emissions is by dividing sources into three generalized categories--area, line, and point sources. This is not the only way to classify sources of pollution, but it does relate well to land use concepts; hence, the utility of land use data is evaluated within this framework in the following discussion.

a. Area Sources - In order to calculate this category of emissions, it is necessary to know the location of residential areas, the types and densities of housing, and population size and distribution.

This information, traditionally supplied in a general land use plan and accompanying text, should be adequate to provide a basis for the calculation of area sources. Population figures also provide a rough estimate of the number of automobiles owned for projecting travel. The housing densities and types generally indicated on the map will give an indication of the number of heating units that can be expected. In areas indicated for potential high density development, emissions from incinerators, if permitted by law, will also have to be taken into consideration. An additional piece of information needed in order to calculate emissions from heating units is the source of energy. This can be obtained from the utility companies in an area or the local planning agency.

Once the sources of emissions have been determined and the potential levels have been established, the evaluator must know the physical characteristics of the area--particularly variations in topography and wind patterns--in order to estimate actual pollution levels. These two factors, of course, will have an effect on whether the pollutants are dispersed or whether they accumulate over an area. In conjunction with this, the proximity of significant amounts of open space should be taken into account, as it has an effect on ameliorating pollution concentrations. Information on open space is also presented on the land use map.

Other components of area source pollution are local commercial and office facilities (with the exception of regional shopping centers). These are indicated on the land use map. Detail as to the type of facility can often be gained through an examination of the existing land use map and the zoning map and ordinance.

Zoning ordinances frequently differentiate among types of commercial uses and often require different amounts of parking space be provided. As previously discussed, the amount of space allocated for commercial use is based on economic forecasts for the area plus consideration of population and disposable income. This type of information gives an indication of the number of cars that will be attracted to an area which can be related to automotive emissions. Some of these zoning requirements may be shifting as a result of the parking plans being developed as part of the transportation control strategies in many urban areas. Commercial areas also produce emissions from heating and, possibly, incineration facilities which should be included in the calculations. These totals from small scale commercial facilities are then included in the area totals.

b. Point Sources - The land use plan, through the studies of industrial demand and the capacity of particular sites for specific industrial uses, provides an indication of potential locations for industrial point sources. Depending upon the level of detail included in the plan, particularly the industrial plan, the broad industrial categories of light, medium, or heavy industry may be indicated on the land use map. If the map is for a less developed area, it may only show one general purpose industrial category. In the latter case, it will be more difficult to determine which areas will, in fact, represent point sources. It should also be noted that the differentiation into several industrial land use types does not indicate the process used or the pollutants emitted.

The distinction made in most zoning ordinances is between light and heavy manufacturing. The difference between the two is based on the degree of noxious effect--noise, odor, dust, etc. The regulations themselves merely list permitted or prohibited industries by industry type. Many of the newer zoning ordinances, however, are prescribing performance standards for industry. These define the maximum amount of noise, smoke, dust, and other external effects that an industry in a given district may produce. If this type of ordinance exists, the maximum levels of emissions by zone may already be known.

Performance standards for industrial districts should be viewed with caution, however, as some jurisdictions do not have the technical capabilities within the planning or zoning department to enforce the standards. In addition, the performance standards for air quality should be reviewed to determine if they do in fact provide for the control that was intended. In other areas the local air pollution control agency can and does enforce performance standards.

Many areas also do a special industrial survey that locates specific types of industry in areas with which they are most compatible. For example, in the comprehensive plan for the City of Philadelphia, the city is partitioned into five zones, each with characteristics of particular interest to industry. These zones are matched with the most suitable industrial type, designated by a three-digit SIC code. This level of specificity, while not locating the exact parcel on which a particular industry is sited, does provide approximate areas where pollution concentrations of a certain type may be expected. If this type of information is available, it would be as an adjunct to the land use plan and should be consulted for use in air quality projections. In any case, industries in the area should be consulted on any plans that they might have for the expansion of facilities. Business or real estate pages of local newspapers often tell of plans for new facilities or industries moving into the area. Chambers of Commerce or local or state industrial development commissions are added sources of information.

The location of public utilities is usually determined by the utility companies. The local planning agency obtains the information from them and reproduces it on a land use map. As utility companies often buy up land in anticipation of need, the projections could reflect this additional knowledge. Depending on the regulations of the state and whether the utilities are publicly or privately owned, they may not be subject to local zoning. In the case where they are not, pollution from other sources may have to be reduced in order to meet the standards where a power plant is to be located in an area.

c. Line Sources - The information gained from the land use plan does not really contribute to the calculation of line sources of pollution, which represent emissions from motor vehicles along principal highways and roads and emissions from aircraft. The studies previously discussed, particularly the urban activity systems, can contribute information to line source calculations. The best data is generally available from the 3-C transportation plan, as described in Section B of this chapter.

Information from the 3-C process includes trip origins and destinations, vehicle miles of travel, average traffic counts, the proportion of trips on transit, and an estimate of speed.

3. The Influence of Land Use Planning on Development

In order for a land use plan (or a comprehensive plan) to be useful as a tool in achieving the objective of air quality maintenance, it must be supported by an enforcement mechanism. If the planning agency or local government does not have the legal power to enforce the plan, then there is no assurance that the plan as developed will ever be implemented. The knowledge that the plan forming the basis of the projections will be implemented also increases the validity of any projections that are made. The power of a plan as part of an overall strategy depends not only on the ability to enforce it but also on the role of a particular plan in the total planning picture. If the plan is part of a total planning process, ranging from the micro, or local, to the macro, or regional, level, then the information it provides has greater applicability and is more useful.

The following sections discuss both of these elements--the mechanisms for enforcement and the integrative aspect of the plan.

a. The Mechanisms for Enforcement - Various types of controls can contribute to the enforcement of the plan. The first level of control lies with those responsible for the development of the plan and its subsequent implementation. Generally, the comprehensive plan and the component land use plan are developed by the planning agency. The land use plan is a guide, and as such it is not legally binding. The comprehensive plan, while not passed as an ordinance, is generally adopted by the legislative body as a policy guide by resolution. The land use plan, however, does form the basis for the zoning ordinance, which is one of the legal mechanisms for ensuring that the plan is implemented. One problem is that in many places the zoning ordinance preceded the plan, which makes rational development more difficult. In other cases, the zoning ordinance may exist without the plan, which means that development can be haphazard.

As land use planning has traditionally been a local concern, the greatest power for enforcement (particularly in the form of zoning) exists at the local level. In one study*, it was found that the agencies with jurisdiction over large areas--state, regional, or county--typically have an extremely limited power base as they are made up of components which have their own authority in the area of land use, as defined by state-enabling legislation.

In a study of the Baltimore-Washington area, it was found that the strengths of land use controls declined as one moved from the central zones outward. Hence, areas experiencing the most rapid change in land use are least equipped to control development, as they often have no zoning. In addition, the planning authority in the region is fragmented; hence, the patterns of land development have largely been shaped by the uncoordinated actions of thousands of private developers and multiple jurisdictions. This means, of course, that the larger the geographic area covered by the plan and the larger the number of component jurisdictions, the less likely that the areawide planning agency will have the tools necessary to enforce it.

Dissatisfaction with the results of local land use controls has caused many states to adopt statewide or regional approaches to land use planning. In Alaska, Colorado, Connecticut, Delaware, Georgia, Hawaii, Maine, Maryland, Massachusetts, North Carolina, Rhode Island, Vermont, and Wisconsin, either a new state organization or an existing agency is required to implement some degree of statewide land use planning or zoning or both, or to carry out some sort of planning and land use regulation aimed at particular classes of land such as wetlands or tidal areas. "In addition, in some states--such as California with the San Francisco Bay Community Development Commission or the Tahoe Regional Planning Agency, New Jersey with the Hackensack Meadowlands Development Commission, or New York with the Adirondack Park Agency--a regional agency has been created to deal with some special problems of land use planning and control. These various measures are primarily directed at resource use problems."* However, they are significant in the fact that they do represent a break with past sole reliance on local land use planning. Some establish state controls that replace local controls; others provide a combination of state and local controls with the statewide concerns clearly dominant.

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* Byron H. Willis, "The Hackensack Meadowlands Air Pollution Study Summary Report," (Lexington, Massachusetts: Environmental Research and Technology, Inc., 1972).

Regional zoning, as differentiated from state level controls, is much more rare, existing only in Jacksonville, Florida; Indianapolis, Indiana; and Nashville, Tennessee. This is due to the consolidation of governments in these areas. The statewide and regional approaches to land use planning and control are, however, too recent to have been fully tested for either their competence, efficacy, or legal powers."**

It should be noted that although an area may have a plan and a zoning ordinance to enforce it, there are ways to change zoning and, in that way, to compromise the land use plan. At the local level, a legislative body or planning commission may grant a rezoning, or a zoning board of appeals may grant a zoning exception or variance. This type of flexibility in the zoning pattern is not necessarily bad, as it may allow for the introduction of innovation, amelioration of a hardship or grievance, correction of a mistake in the original zoning, or accommodation to changed conditions. However, it does decrease the reliability of projections based on the plan.

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* Marion Clawson and Harvey S. Perloff, "Alternatives for Future Urban Land Policy," Modernizing Urban Land Policy, edited by Marion Clawson (Baltimore: Johns Hopkins University Press, 1973), p. 222.

** Ibid., p. 222.

The existence of effective land use controls is critical to the use of land use planning for maintaining air quality. There are presently several techniques for controlling urban and suburban growth and development, including:

- Location and timing of public improvements such as roads, sewers, sewer treatment plants, and water lines.
- Lending policies and the restrictions which may be imposed by private lending agencies and the government agencies that supervise them or insure their loans
- Government subsidies, loans, and other programs for renewal, development, and redevelopment
- Public land use controls - zoning, subdivision regulations, building codes, health regulations
- Tax policies that would encourage the inclusion of environmental objectives into the private decision-making process

Many of these elements are generally delineated in the Capital Improvements Plan which is the planned budget for 2 to 5 years for the local jurisdiction.

The following section discusses zoning in greater detail as it is the predominant mechanism for land use control. In general, the zoning power may be transferred by the state, through enabling acts to the governments at either the local, county, or regional level. Some states authorize all three types of zoning while others restrict power to the local level. This decision is generally based on the nature of development within the state and the system of land use control that would appear to be appropriate.

As the concerns of a municipality, county, and regional agency usually vary considerably, the zoning ordinance, in terms of the provisions and the districts or zones defined, will also vary. Zoning at the regional level, where it exists, will differ from that of the municipality or the county in that it represents a coordinating function and usually will be carried out by a body with representation from the constitutent counties. A regional planning commission constituted in this fashion may have the authority to prepare various zoning codes and ordinances for its area, but these must be approved and adopted by the constituent counties before they have the force of law.

At the local level, where zoning has been the traditional regulating mechanism, it has been shown that "zoning controls have been of limited value in guiding new suburban land development. The typical suburb is either unable or unwilling to enact zoning and other controls that are strong enough to effectuate a general plan for the area. The difficulty, however, has been political, not legal."*

Because of the local basis for zoning, the regulations have often proved obstructive to the development of land use plans at a broader scale. In the past, land use zoning was used by units of local government for local ends; hence, when it came to the issue of overall economic and social development, and the implementation of a metropolitan strategy, local land use zoning and controls have been notably deficient. The result has been that development has generally assumed the form of uncontrolled sprawl.

Gradually, however, there has been a change in the thinking about land use regulation away from the belief that the purpose of the regulation was for the protection of the commodity value of land. There is a realization that important social and environmental goals require more specific controls on the use that may be made of scarce land resources. This change in attitude is seen not only in the new state role in land use regulation but also in the actions of many local governments. Modern zoning ordinances typically rely less on pre-stated regulations and require the developers to work with local administrative officials in designing a type of development that fits more closely into the surrounding area. Typical of this new direction are planned unit development (PUD) zones which encourage larger scale development in which the various land uses are arranged and designed according to an overall plan for the specific site as opposed to the traditional lot-by-lot development. There is also a greater tendency on the part of local governments to develop more specialized use districts that permit only those uses appropriate to the geographic area rather than to some abstract category of uses. This is evidence of the growing attempt to tailor land use regulations to local needs. Finally, and probably most significantly, for the purposes of planning, there has been a rapid increase in "recent years in local zoning and subdivision regulations in relatively undeveloped areas. Here the concern is with the development of optimal long-range land use patterns."* This new, more comprehensive approach to zoning may eventually eliminate the over-use of re-zoning, exceptions, and variances that tend to distort the patterns.

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* Marion Clawson, "Editor's Introduction," Modernizing Urban Land Policy, ed. Marion Clawson (Baltimore: Johns Hopkins University Press, 1973), p. 6.

b. The Integrative Aspect - If the land use and comprehensive plans are to be useful tools, they should be part of a comprehensive integrated effort to achieve this objective; the broader the base of the plan, the more likely that it will have some effect. This section discusses how the planning agency interfaces with other agencies that might provide specialized information, as well as the relationship of the plan to other land planning efforts.

As the concern for the environment is only just beginning to be incorporated into the comprehensive land use planning process, there has traditionally been very little need for coordination between the local planning agency and any existing environmental agencies in the area. The present concern with expanding the definition of the comprehensive plan to include environmental considerations, and the requirements of the National Environmental Policy Act (NEPA) and the A-95 Review have probably resulted in an increased level of interaction between these two groups. In the area of air pollution, the Hackensack Meadowlands Air Pollution Study has indicated that there is a lack of a clear distinction between the responsibility of the planner for the abatement of air pollution problems in the long term and that of air pollution control officials. It was found that many planners felt that it is not within their jurisdiction to incorporate air pollution into the planning process, but rather felt that more effective solutions could and should be achieved by direct control of emission sources through the air pollution control agencies and their powers of regulation and enforcement. It would appear that a greater coordinative effort is necessary so that both strategies are implemented, as well as being mutually supportive. This type of coordination is particularly important for the control agency so that control strategies can be closely related to the land use patterns that are developed.

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* Fred Bosselman and David Callies, The Quiet Revolution in Land Use Control (Washington, D.C.: Government Printing Office, 1971), p. 317.

The relationship of a plan to plans of a larger and/or smaller scale depends to a large extent on the existence of a standard system of land use categories throughout the area under consideration. There has been a great problem of comparability of plans as many areas use their own definitions and collect different types of data at different levels of detail. This means that local land use plans cannot always be summed to produce a regional plan. There are examples where the land use plan for a region does represent a compilation of the land use plans of the component jurisdictions. In this case, greater specificity in regional projections can be gained from looking more closely at the studies that went into the land use patterns for each of the component jurisdictions. Because of the variability of the plans, it is difficult to say where regional and local plans are compatible and where they are not.

A significant source of conflict may occur in the case where local plans may reflect community goals over which they have very little control. For example, a no-growth policy in some local jurisdictions may be an appropriate response to the community's ability to provide adequate facilities and services. However, the local government may possess neither the regulations nor the will to withstand private development. On the other hand, especially in less developed areas, local "boosterims" and wishful thinking may result in vast areas being planned and zoned for commerce and industry with little support by economic realities. The evaluator will have to make a decision on a case by case basis.

c. The Planning Document as a Reliable Source of Information - The degree to which land use plans and zoning maps will be useful to air pollution control will vary widely from agency to agency because of the uncertainty inherent in the findings and recommendations contained in planning documents. Some of the factors that must be taken into consideration are:

- A characteristic of almost all plans is that they are not current. The base year for much of the socioeconomic projections is information from the census. Techniques for updating such information vary considerably. Land use inventories are continuously updated in some agencies, while others may be several years old. In addition, local actions affecting the plan may not be reflected on the plan.
- Many plans may be so general as to be of little use as a guide for quantifying and locating future problems in air resource management. In such cases, the text of the plan may be more important than the map, as specific development policies or guidelines may be well articulated. For example, the planning map may not indicate the location of commercial facilities while the text may describe locational criteria, service

areas, range of facilities according to function, size, etc. In the decision-making process, then, the planners would not be committed to a specific location in advance but would measure private development proposals against these criteria set out in the plan.

- Planning maps may indicate significant areas for urban development which would not necessarily be reflected on the zoning map. In such cases, the local strategy is to "under zone," thereby requiring all potential developers to appear before local planning and zoning boards and legislative bodies to gain plan approval. Under such circumstances, the local government is likely to have more influence on the type of development that occurs than if the developer already has the appropriate zoning. The plan indicates the proposed land use and provides a guide for zoning action.

4. The Potential for Change

An effective comprehensive plan is not a static document but rather represents a dynamic process that is regularly updated to reflect new conditions and objectives. The incorporation of new information with regard to the relationship between land use air quality and other environmental aspects such as water quality, should be part of the updating procedure. The review process is particularly important for plans in areas that are still developing but are already experiencing air pollution problems.

The basic guidelines for the development of a comprehensive plan suggest that the plan should be reviewed annually. "Once a year the legislators should re-examine the plan and consider possible amendments."* These amendments would normally be initiated by the planning staff. They would then be screened by the planning commission and forwarded to the legislators. "The importance of the annual review cannot be overemphasized.

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* Alan Black, "The Comprehensive Plan," Principles and Practice of Urban Planning, edited by Goodman and Freund (Washington, D.C.: ICMA, 1968), p. 370.

This is the main process which is intended to assure that the plan will be kept up to date. If it is neglected it is possible that the plan will "ossify" and be ignored. Annual review, however, is a fairly recent innovation."*

There should be a major reconsideration of the entire plan after five or ten years. This should provide for an overhaul of the entire plan, including new surveys, updated projections, and the restudy of major alternatives. The effort expended on this should be similar to that put into the original plan, and the same general procedures should be followed. The rationale behind this step is that amendments made at annual review time will not suffice to keep the plan current after an extended span of years. Gradual changes (particularly those caused by rezonings, variances, and exceptions) may be imperceptible.

The ability to change the plan may not always serve the best interests of those interested in air quality. That is why it is incumbent upon those who have responsibility in this area to review plans at the operative level and to provide inputs that will provide a basis for developing plans that contribute more to the achievement of air quality goals.

B. THE 3-C PROCESS

The term "3-C process" comes from the Federal-Aid Highway Act of 1962 which requires that all programs for Federal-Aid Highway Projects approved after July 1, 1965, in urban areas of more than 50,000 population must be based on a Continuing, Comprehensive transportation planning process carried on Cooperatively in the state and local communities.

1. Current Practice

Generalizations about the process and procedures followed in the planning studies are very difficult because no two studies follow identical methods or procedures. All studies vary widely in terms of the level of detail for specific portions of the study and the analytical process used to analyze and evaluate data in the planning process.

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* Ibid., p. 370.

Although the 3-C transportation planning process has been implemented for several years, the level of sophistication and the degree of accuracy of the plans varies considerably throughout the nation. In many of the larger urban areas travel simulation models have been calibrated to local conditions and validated over time so that the accuracy of the models is known. In other areas the updating and validation procedures have not been so well performed. However, the Federal Highway Administration, through the certification process which accepts the plans and, thus approves projects, for Federal funding, tends to ensure the reliability of the 3-C process. It should be noted, however, that the process as described below is not always rigorously followed; nor will all of the elements necessarily be readily available to air quality maintenance planners.

While there is considerable variation in the detailed procedures used in each study, the comprehensive planning process requires that certain concepts are common to all 3-C planning efforts. These include evaluations of existing and future economic, population, and land use data; estimates of future demands for all modes of public and private transportation; inventories and analyses of all existing transportation facilities; the development of a comprehensive transportation plan; and the implementation of a continuing program to monitor and, as necessary, revise the original transportation plan. The guidelines for implementing the 3-C process are documented in a series of Policy and Procedure Memoranda (PPM) prepared by the Federal Highway Administration (FHWA). Copies may be obtained from the regional FHWA office or the local 3-C transportation planning agency. (The relevant document is PPM 50-9.)

Figure II-1 shows the generalized activities of almost all 3-C planning processes grouped into the following four phases:

- Phase I: Data Collection - Various surveys are conducted to provide a detailed picture of existing travel and socioeconomic conditions in the study area.
- Phase II: Analysis - Analytical methods are used to develop an understanding of the factors influencing travel demand and develop procedures for projecting future travel demand and transportation requirements.
- Phase III: Projections and Plan Development - Anticipated land use and land activity are projected to future years, travel demand in the study area is forecast, alternative transportation strategies are developed and tested, and a final transportation plan is developed.
- Phase IV: Implementation and Continuing Planning - Under a continuing program to monitor the planning concepts used in the development of the original transportation plan, the transportation strategy developed in Phase III is implemented and its effectiveness monitored.

The end results of this process are twofold. First, based on a detailed investigation and analysis of the existing situation, a transportation plan and program can be developed that serves as a common framework for all agencies charged with transportation systems improvement and operation in the study area. Second, it provides the basic information and procedures for continually reviewing the appropriateness of transportation strategy as required by changing events and changing community goals and objectives. In almost all major urban areas, the transportation planning process is in Phase IV, Implementation and Continuing Planning.

2. Legislative Requirements

The Federal-Aid Highway Act of 1944 was the first Federal program to provide regular Federal-Aid highway funds for use in urban areas. The 3-C planning process in all urban areas with population over 50,000 was

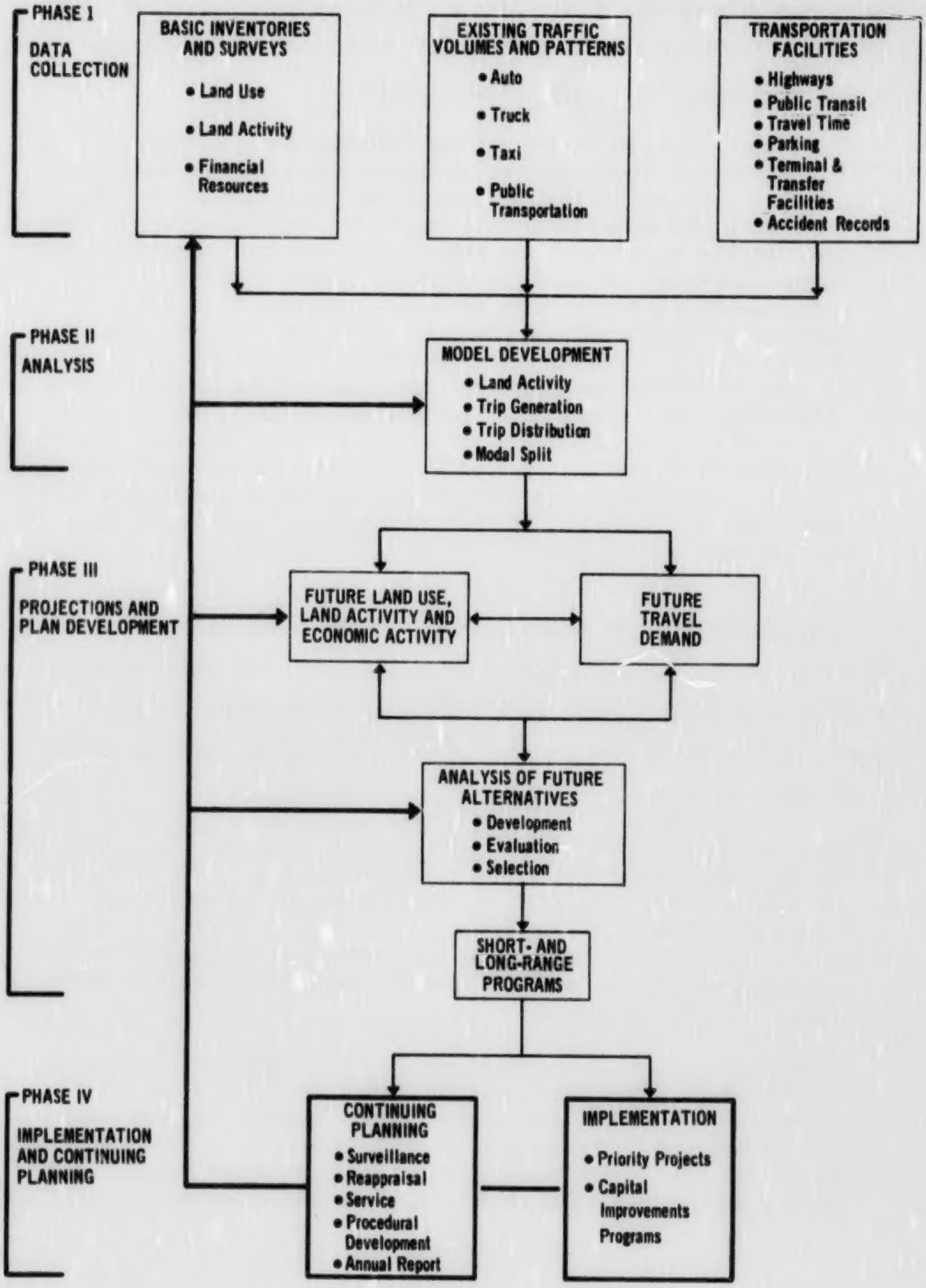
PHASE I
DATA COLLECTION
BASIC INVENTORIES AND SURVEYS
• Land Use
• Land Activity
• Financial Resources
EXISTING TRAFFIC VOLUMES AND PATTERNS
• Auto
• Truck
• Taxi
• Public Transportation
TRANSPORTATION FACILITIES
• Highways
• Public Transit
• Travel Time
• Parking
• Terminal & Transfer Facilities
• Accident Records
PHASE II
ANALYSIS
MODEL DEVELOPMENT
• Land Activity
• Trip Generation
• Trip Distribution
• Modal Split
PHASE III
PROJECTIONS AND PLAN DEVELOPMENT
FUTURE LAND USE, LAND ACTIVITY AND ECONOMIC ACTIVITY
FUTURE TRAVEL DEMAND
ANALYSIS OF FUTURE ALTERNATIVES
• Development
• Evaluation
• Selection
SHORT- AND LONG-RANGE PROGRAMS
PHASE IV
IMPLEMENTATION AND CONTINUING PLANNING
CONTINUING PLANNING
• Surveillance
• Reappraisal
• Service
• Procedural Development
• Annual Report
IMPLEMENTATION
• Priority Projects
• Capital Improvements Programs

Figure II-1. Generalized activities of the 3-C planning process.

established in response to Section 9 of the Federal-aid Highway Act in 1962, which amended Chapter I of Title 23, United States Code, by the addition of a new section, 13A, which states:

> It is declared to be in the national interest to encourage and promote the development of transportation systems embracing various modes of transport in a manner that will serve the states and local communities efficiently and effectively. To accomplish this objective the Secretary shall cooperate with the states, as authorized in this title, in the development of long-range highway plans and programs which are properly coordinated with plans for improvements in other affected forms of transportation and which are formulated with due consideration to their probable effect on the future development of urban areas of more than fifty thousand population. After July 1, 1965, the Secretary shall not approve under Section 105 of this title any program for projects in any urban area of more than fifty thousand population unless he finds that such projects are based on a continuing comprehensive transportation planning process carried on cooperatively by states and local communities in conformance with the objectives stated in this section.

A description of all Federal, state, and local legislation as it applies to the current 3-C planning process in all urban areas is beyond the scope of this document. The following is a listing of the major Federal legislation and regulations relating to the 3-C planning process and air quality control.

Clean Air Act of 1970 (42 USC 1857 et seq.). Purpose: To require the Environmental Protection Agency to review and comment in writing on the environmental impacts of any matter relating to duties and responsibilities granted pursuant to this Act or other provisions of the authority of the Administrator when such impacts result from a project to which section 102(2)(C) of the National Environmental Policy Act of 1969 applies.

Federal-Aid Highway Act of 1970 (23 USC 109). Purpose: To require the Secretary of the Department of Transportation to issue planning and design guidelines to be applied to all highway projects which are approved after the issuance of such guidelines. Under the FHWA guidelines for Section 109(h) (PPM 90-4), each highway agency shall develop an Action Plan which describes the organization to be utilized and the process to be followed in the development of Federal-aid highway projects from initial system planning through design.

23 USC 109(h) directs the following:

> Not later than July 1, 1972, the Secretary, after consultation with appropriate Federal and state officials, shall submit to Congress, and not later than 90 days after such submission, promulgate guidelines designed to assure that possible adverse economic, social, and environmental effects relating to any proposed project on any Federal-aid system have been fully considered in developing such project, and that the final decisions on the project are made in the best overall public interest, taking into consideration the need for fast, safe, and efficient transportation, public services, and the costs of eliminating or minimizing such adverse effects as the following:
>
> (1) air, noise, and water pollution
> (2) destruction or disruption of man-made and natural resources, aesthetic values, communtiy cohension and the availability of public facilities and services
> (3) adverse employment effects, and tax and property value losses
> (4) injurious displacement of people, businesses and farms
> (5) disruption of desirable community and regional growth
>
> Such guidelines shall apply to all proposed projects with respect to which plans and specifications and estimates are approved by the Secretary after the issuance of such guidelines.

23 USC 109(j) directs:

> The Secretary of Transportation to assure that highways pursuant to Title 23, USC, be consistent with any approved plan for the implementation of any ambient air quality standards for any air quality control region designated pursuant to the Clean Air Act, as amended (42 USC 1857, et seq.).

The Urban Mass Transportation Assistance Act of 1970 and Section 204 of the Demonstration Cities Act of 1966, further clarified by Bureau of the Budget Circular A-95. Purpose: To require submission of all applications for the planning or construction of facilities using Federal loans and grants to the designated areawide agency responsible for metropolitan and regional planning prior to Federal approval of the application.

These agencies (A-95 Clearinghouses) have the responsibility for reviewing and commenting upon all applications for Federal assistance for public projects to ensure that "to the maximum extent possible, consistent with national objectives, all Federal aid for development purposes shall be consistent with and further the objectives of the state, regional, and local planning."

Air Quality Guidelines for Use in Federal-aid Highway Programs 23 CFR 770). Purpose: To promulgate air quality guidelines for use in planning and construction of proposed highway improvements constructed pursuant to United States Code Title 23. Under these guidelines, highway agencies planning, constructing, and maintaining highways pursuant to 23 USC shall consult with appropriate local, state, and Federal air pollution control agencies to ensure that decisions on highways are consistent with approved State Implementation Plans and that adequate consideration is given to preservation and enhancement of air quality.

3. Agencies and Groups Involved in the 3-C Process

All state highway agencies that propose projects for which plans, specifications, and estimates are approved by FHWA must develop an "Action Plan" as required under Section 109, Title 23, United States Code. The "Action Plan" for each state highway agency specifies for that agency the specific organizational structure and processes to be followed in the development of Federal-aid highway projects from initial planning through design. Therefore, the organizational structure and proceedings for each agency vary to reflect the unique situation of each state. The guidelines for developing the "Action Plan" are contained in PPM 90-4.

The organizational structure for individual 3-C planning studies that are currently in the continuing planning phase can also be found in the "Operations Plan for Continuing Urban Transportation Planning" developed for each study. FHWA Instructional Memorandum 5-4-68 (IM-5-4-68) contains the guidelines for the development of the operations plan.

The specific organizational structures for each of the existing 3-C planning programs can be obtained by reviewing the appropriate "Operations

Plan" and "Action Plan." The individual organizational structure for each 3-C program varies to some degree. In most studies the following types of committees are formed:

- Policy Committee (sometimes called a Policy Board, Coordinating Committee, Steering Committee, etc.). - This committee is composed of local elected officials and representatives of agencies or organizations designated by the state to provide policy guidance and direction for the study. In most cases, this committee also includes representatives of the state and FHWA.

- Technical Advisory Committee - This committee generally consists of staff appointed from the various state, regional, and local governmental agencies participating in the study, plus representatives of other agencies or organizations having special skills in various study items or a special interest in the transportation planning process. In general, it is the responsibility of the Technical Advisory Committee to direct the study and review all procedures for technical adequacy and to make recommendations to the Policy Committee.

In some areas, citizens' committees have been formed to aid in the establishment of communications between the technical staff and the public. These committees also help provide lines of communication between the public and the governmental units represented on the Policy Committee.

4. General Description of the 3-C Process

Generalizations about the 3-C planning process are difficult because no two studies follow identical working methods and procedures. The specific type of data collected, the level of detail, and the level of analysis performed in each study vary to a considerable extent. The following is a generalized description of the types of data collected and the types of information developed in each of the four phases of the 3-C process.

a. Phase I: Data Collection - The major inventories and surveys conducted in the initial phase of the 3-C planning process can be combined into three general classes:

Basic Inventories and Surveys - The land use and land activity data in general are collected at the traffic zone level. The number of traffic zones within a study area varies in total number from several hundred to more than 4,000 and from a single block to many square miles in area. Traffic zones are generally small geographic areas in the more populated areas and large geographic areas in the outlying, less populated areas.

The land use is generally measured in acres per zone and includes the following classifications:

- Low density residential
- High density residential
- Industrial
- Commercial
- Agricultural
- Public and quasi-public
- Vacant
- Roads and streets

In some cases the land use codes contained in "The Standard Land Use Coding Manual," Urban Renewal Administration and U.S. Bureau of Public Roads, dated January 1965, are used. Land activity by traffic zone includes:

- Population
- Dwelling units
- Median and/or mean family incomes
- Auto registration
- Employment (by standard industrial classification code)
- Labor force
- School enrollment

In most studies historical land use and land activity information and trends are also surveyed and tabulated. Surveys are also made in many of the studies to determine the financial resources available for the implementation of the transportation plan. These surveys include the source and amount of revenue used for the construction, maintenance, and operation of transportation facilities for the previous 5 to 10 years.

Existing Traffic Volumes and Patterns - Three basic types of surveys are made to determine the number, purpose, mode, and time of day trips are made by all persons and vehicles within, into, out of, and through the transportation study area. These three surveys are the home interview, external, and truck and taxi surveys.

In the home interview survey, a sample of all dwelling units within the study area is selected, and all trips made by the residents of these dwelling units are recorded. The sample size varies from 12 percent for small urban areas to 4 percent or less for very large urban areas. The characteristics of the dwelling unit are also recorded in this survey. These characteristics include number of persons in the household, number of cars owned, total household income, number of persons employed, type of employment, and age of residents. The data for each trip made on a given day by each member of the household includes the purpose of the trip, the origin and destination of the trip, the mode of travel (auto driver, auto passenger, transit passenger, walk to work, etc.), the time the trip began and ended, and the number of passengers in each vehicle.

In the external survey, 20 to 50 percent of all vehicles crossing the boundary of the study area (called the external cordon line) on major routes on a given day are interviewed. The origin and destination of each trip, trip purpose, number of persons per vehicle, type of vehicle, time of interview, etc., are recorded for each vehicle interview at the external cordon.

In the truck and taxi survey, a 10 to 20 percent sample of all trucks and taxis garaged within the study area is selected. All trips made by these vehicles on a given day are recorded. The same type of information as collected at the external cordon line is recorded for each trip.

All of the trip interview data is expanded to reflect the sample rates; it is checked, and verified so that travel information reflecting all trips made on a typical day of the survey period is produced.

In some studies, an on-board transit survey is also conducted. In this type of survey, a large sample of the transit riders is interviewed to provide in-depth transit travel pattern data. Two common types of transit surveys are direct interviews conducted on the vehicle by trained personnel and the postcard survey in which questionnaires are distributed to passengers on the transit vehicle.

From the expanded travel survey data, a detailed tabulation of the number of trips made between any zones within the study area by time of day, trip purpose, and mode of travel is developed.

Transportation Facilities - The third general class of inventories and surveys conducted in the first phase of the 3-C planning process is a detailed inventory of all transportation facilities within the area to determine the quantity and quality of the existing transportation system. Included are:

- Inventory of the characteristics of all highway facilities including pavement width, right-of-way, intersection approach width, all traffic control and traffic engineering features, as well as surveys of existing traffic volumes. From this data, existing levels of service and the capacities of the facilities are determine.
- Surveys of the existing transit system and its usage. This information includes location of routes by type of service, transfer points, frequency of service, and operating characteristics and statistics.
- Travel time studies to determine the peak hour and off-peak hour speeds on various segments of the transportation facilities.

- Parking surveys to identify the quantity and usage of existing parking in the major urban areas.
- Location and inventory of major goods terminals and transfer facilities.
- Tabulation and analysis of accident data by location, type of facility, and frequency as a measure of safety of the system.

From the facilities survey data, highway and transit "networks" are developed. These networks are computer-processable representations of the existing highway and transit system operating in the area.

The trip data from the travel survey is used in connection with these networks and a system of computer programs to produce "network assignments" is developed. These assignment procedures allow zonal trip interchange data to be allocated to specific elements of the transportation system--transit trips to various combinations of transit routes, auto trips to various highway facilities, etc. Through these procedures and techniques, it is possible to approximate the movement of people and vehicles between various land activities on the existing transportation facilites.

The information available from the assignment techniques includes vehicle miles of travel, average speeds on various components of the network, types of trips on various segments of the transportation facilities, vehicle and person trip ends by traffic zone, average trip length in miles and time for various types of trips and modes of travel, and the various area-to-area movements that result in specific volumes on individual transportation facilities or combination of facilities.

b. Phase II: Analysis - The fundamental purpose of the second phase of the transportation study is to develop procedures to project future travel demands. The analysis is aimed at obtaining an understanding of the fundamental characteristics of the travel data obtained in the first phase. These characteristics are quantified and expressed in mathematical formulas that relate travel demand to the land use, land activity, and transportation system characteristics. The analysis is focused on quantifying the answers to specific questions, such as: What are the relationships that exist within the transportation study area between the magnitude of trips generated by or attracted to each land activity, and the intensity of that activity at each location? What effect does spatial separation of certain land activities have on the number of trips made between one portion of the study area and another? What unique patterns exist in the present distribution of travel demands? How are these patterns explained, and how will they relate to the transportation demands of the future? How reliable and how stable are the mathematical formulations used to develop travel demand estimations and project travel demands? What factors influence the number of trips made within the area?

In general, the following types of mathematical models are developed and calibrated in the larger transportation studies.

Land Activity Models - These models provide a technique for distributing regional activity levels to small areas and subsequently to drive other land activity and socioeconomic data related to the activity distribution. Three general types of activity allocation models are in current use. They are trend analyses, econometric, and probability-based models. (See Appendix C for detailed discussion of these models.) It should be noted that quantified land activity modeling as discussed in Appendix C is applied in only a few urban areas. The projection of land use and land activity has been developed using procedures that are substantially judgmental.

Trip Generation Models - These models provide a technique for formulating the relationships between the trip generated in a traffic zone and the characteristics of the zone such as land use and land activity measures. Many alternative techniques are used for trip generation. The two most common techniques are multiple-regression analysis and cross-classification analysis. The multiple-regression analysis is a statistical technique in which multivariable equations are developed to relate land activity measures within a zone to the number of trips by trip purpose generated by the zone.

Cross-classification is a technique in which the tripmaking attributes of persons or households by trip purpose can be estimated when the changes in two or more other attributes of the person or household are accounted for. In this technique a number of independent variables are stratified into two or more groups creating a matrix. Observations on the dependent variable are then allocated to the cells of the matrix, based on the values of the independent variables. For example, total person trips per dwelling unit could be developed based on the median household income.

Trip Distribution Models - Once the zonal trip generation is developed, the trip distribution models are applied to predict the distribution of these trips among the zones within the study area. The three most common trip distribution models are the growth factor technique, the interviewing opportunities model, and the gravity model techniques. In the growth factor technique, such as the Fratar method, an existing trip distribution is modified by applying factors representing the projected growth of each zone in an iterative process to the existing travel data until the desired trip growth of each zone is reached. This technique generally is used only in smaller and slowly growing areas.

The intervening opportunity model is a probability function based on the premise that total travel time from a point is maximized, subject to the condition that every destination point considered has a stated probability of being acceptable. More precisely, the opportunity model states that the probability that a trip will terminate within some volume of destination points is equal to the probability that this volume contains an acceptable destination, times the probability that an acceptable destination closer to the origin of the trip has not been found. The model operates on inputs concerning the total trips originating in a zone, the total destinations in a zone, and empirically derived probability constant based on the average density of trip ends and the average trip length.

The gravity model is the most widely used of the three trip distribution techniques. It is based on the assumption that trips produced at an origin and attracted to a destination are directly proportional to the total trips produced at the origin, the total trip attraction at the destination, an empirically derived impedance measure for interchange travel between zones, and in some cases a socioeconomic adjustment factor.

Modal Split Models - These models disaggregate total person trips into auto-driver trips, auto-passenger trips, and transit-passenger trips. Three types of modal split models are commonly used: direct transit and auto trip generation, trip-end modal split, and trip-interchange modal split. In the direct trip generation model, transit and auto trips are developed directly from trip generation equations. The trip-end modal split model uses the total person trips produced by the trip generation equations and produces an estimate of the auto and transit trips prior to trip distribution. The trip-interchange modal split models use the person-trip distribution from the trip distribution models.

c. Phase III: Projections and Plan Development - Using the techniques described above the land use, land activity, economic activity, and travel demand are projected to future years.. These projections, or forecasts of expected activity levels, form the basis for testing of alternatives and evaluating results in light of the overall goals and objectives of the communities in the study area. This procedure results in the recommendation of the regional transportation program based on the established objectives and standards of all of the communities contained within the study area. Preparing alternative transportation plans calls for imagination and judgment as well as a deliberate attempt to arrange the transportation facilities so that future transportation strategies can be developed within the limitations of financial constraints and community values.

Each of the alternatives tested must be evaluated in light of the total developments of the area as well as the specific facilities and their effect on their immediate environment. Existing and planned renewal and redevelopment areas, housing projects, new subdivisions, industrial districts, regional parks, open space, etc., must be taken into account. The selected plan must be as compatible as possible, and must, to the extent possible, promote other community goals and objectives, including air quality, energy conservation, and mobility.

The final result of this phase of the planning study is a coordinated and acceptable plan of action to meet the needs generated by the forecasted land activity, land use, and traffic demand and to provide the study area with the best solution to the transportation needs that will exist in the future.

Projection of Land Use and Land Activity - In the plan development and analysis process carried out in many metropolitan areas, multiple land use and transportation plans are considered, while in others, transportation alternatives are developed in relation to a single land use plan.

In those studies in which only a single and use plan is used, the first step in the projecting procedure is to estimate the future land use and land activity for the entire study area. These projections are then disaggregated so that the employment, population, and other land activity measures are distributed into the subareas of the region.

Travel Demand Forecasts - The next step in the projecting procedure is to convert the future land use and land activity into future travel demand. This is done by applying the mathematical procedures developed in the analysis phase to the projected land use and land activity information. The result of this procedure is a systematic and detailed forecast of the location and magnitude of future travel demand throughout the area. Once the future travel demand is established, it is studied in relationship to the available transportation system in the area. In this way, the location of future facilities and services is developed and evaluated.

In the metropolitan areas where alternative comprehensive land use and transportation plans are tested, the procedures for developing alternative land use and land activity vary greatly. In some studies various land use and land activity concepts such as radial corridor development, multitown (satellite towns) development, compact city, spread city, linear city, etc., are selected as general land use and land activity forms. Projections of future land use and land activity are developed based on these concepts and various alternative transportation plans. In some studies, the type and density of activity projected for a given area is strongly influenced by the relative level of proposed transportation facilities and service available to the area. In other studies, various combinations of these approaches for developing alternative land use and transportation plans are used.

Analysis of Alternatives - In addition to the variations in developing land use and land activity projections, several transportation alternative concepts are used in most studies to develop and test alternative plans. These include transportation variations such as high-intensive plans, freeway-intensive, radial systems, grid systems, minimum improvement, maximum improvement, as well as various combinations of these network concepts.

In the evaluation of each of the land use plans and transportation alternatives, many types of procedures and techniques are emphasized. One generalized procedure, common to almost all studies, involves the development of future travel demands, the assignment of these travel demands to the transportation network, and the evaluation of the assigned volumes relative to some performance measures.

In addition to the evaluation of the performance of a single land use and/or transportation plan, comparisons of alternatives are also made in most areas. In many studies, comparisons and evaluations to a no-improvement alternatives, in which only the existing transportation facilities and service are included in the network, are also made.

Performance measures used in these evaluations at both the regional and subregional levels include total trips by persons and vehicles by mode and purpose; travel times and cost by mode and trip purpose; vehicle miles of travel, and vehicle hours of travel; average speed by mode and facility type; measures of system capacity relative to travel demand by mode and facility type; trips to and from major subareas (such as the CBD) by mode and trip purpose; and average length by mode and trip purpose.

Another type of system evaluation commonly used is an economic analysis such as the benefit-cost analysis. In this type of analysis, facility cost and transportation cost by both the public and private sector are estimated. Comparisons are then made of the benefits derived from decreased travel distance and travel time and the cost of providing the proposed facilities and service.

Performance measures of accessibility provided by the highway and/or transit system to various subareas as well as as general measures of accessibility to population, employment, and other land use activity are also developed by some studies. Many forms of analyses are developed in various studies to evaluate the impact of various land use plans and policy elements. Incorporated in many of the studies are evaluations of the impact of various public policies regarding the transit systems, parking facilities, sewer policies, open space, land use control for commercial and industrial development, etc.

From the analysis of alternative land use and transportation plans, one of the alternatives, or a new plan developed from several alternatives, is selected for implementation. The selected plan may apply to the short range (5 years) to correlate with priority programs for funding and planning at state and local levels; longer range plans are used to guide development over time.

d. Phase IV: Continuing Planning and Implementation - Most of the 3-C transportation studies are complete through the first three phases of the study process and are now in the implementation and continuing planning phase of the study. For these studies an "Operations Plan for Continuing Urban Transportation Planning" has been prepared. Each of these plans includes:

- An outline of the organizational structure for performing continuing planning, including related committees
- An outline of the scope of the continuing planning, with a breakdown of the functional and financial responsibilities of all participating agencies
- A description of the surveillance methodology to be employed in identifying changes in land development and travel demand, including assignment of responsibility for providing inputs to various models
- A description of the land use and travel projection procedures to be utilized, including specific information required for the various analyses
- A description of any work remaining to be completed on the ten basic elements (PPM 50-9 paragraph 5) including a schedule for completion of work. The ten basic elements are:
    - Economic factors affecting development
    - Population studies
    - Land use
    - Transportation facilities, including those for mass transportation
    - Travel patterns

- Terminal and transfer facilities
- Traffic control features
- Zoning ordinances, subdivision regulations, building codes, etc.
- Financial resources
- Social and community value factors

In the FHWA guidelines for the continuing planning process (Instructional Memorandum 50-4-68) five elements are identified:

Surveillance - includes studies of annual population growth, traffic counts, transit usage, and changes in land development policy.

Reappraisal - is a three-level procedure.

Level 1, Routine Review, is intended to determine annually if changes in urban development are in accordance with projections.

Level 2, Major Review, is usually conducted every five years; it includes a check on the accuracy of the travel forecast process to simulate actual traffic.

Level 3, Plan Reevaluation, is a complete reevaluation of land use and transportation plans conducted at least every ten years. It includes reassessment of goals and objectives of population and employment forecasts, an analysis of the networks, parking policy and transit, and a restudy of finances for improvements and priority projects.

Service - includes supplying data to other agencies, assisting in development of state and Federal needs estimates, and assistance to urban agencies responsible for implementing portions of the plan.

Procedural Development - provides for update of techniques for projection and plan development and for research in these areas.

Annual Report - is intended to serve as an informational document for technicians, decision-makers, and citizens. It includes a quantitative summary of all surveillance items as well as an assessment of the process as described by the implementation program, a check on consistency of development with the plan, and deviations from the plan.

Implementation of the plan is carried out through the preparation and adoption of priority programming and budgeting, and subsequently through the design and construction phases of a project. Priority projects are defined, generally by the state department of transportation (or the state highway department) and the local jurisdictions depending on which is the implementing agency. These programs are based on recommendations of the 3-C planning process. The criteria for designation of priorities include design volumes, land activity, funding requirements, etc.

In the short term, priority projects are placed in capital improvements budgets submitted to state and local legislative bodies for funding. These are generally annual budgets; they may be either cash flow or appropriation budgets. The budget requirements are described in a full 5-year program.

5. Data Sets and Formats

Many reports, technical memoranda and tabulations, and summaries of data are produced through the 3-C planning process. Because of the dynamic nature of the planning effort in many areas, problems can occur in the evaluation of published reports and tabulations of data. In many cases, detailed documentation of current practices and projections, which may differ substantially from those previously documented, are either not available or exist only in the form of technical memoranda with limited distribution. Thus, efforts to utilize transportation planning data must be accomplished through staff of the local 3-C planning agency.

a. Reports

Annual Report - Each of the 3-C agencies is required to prepare an annual report as described above. This report contains a summary of the current planning activity and the surveillance program as developed in the operations plan for the individual study. This report also contains the 5-year improvement program for the study area.

The Operations Plan - This plan for each study in the continuing phase describes the organizational structure, scope of the continuing planning and the methodology and procedures used in the study. The operations plan is revised when significant changes occur in the study operations.

The Unified Work Program - This report is developed annually by 3-C study areas and describes the allocation of funds for the planning activity.

The Action Plan - Each state has developed an action plan describing the organizational structure and processes to be followed in the development of Federal-aid projects from initial system planning through design.

Study Reports - In addition to numerous technical reports generated by each study, several summary reports are typical to most studies:

- Base Year Findings Report - This report presents in a summarized and graphic form the results of the data collection phase of the study.
- Model Development Report - This report contains a description of the development and validation of the models used in the study.
- Forecast Report - This report contains a description of the land use, land activity and travel forecast.
- Transportation Plan Report - This report describes the procedures used to develop and evaluate the various transportation and land use alternatives, and the resulting plan or plans developed from this analysis

Capital Improvements Plan - This is the short- and long-range dollar budget for implementing each phase of the plan. It is from this budget, when adopted, that state and local funds are allocated for transportation projects on a priority basis.

b. Computer and Other Data

Most of the 3-C studies have compiled the following types of data:

Existing and Projected Land Use and Land Activity Data by Traffic Zone - In most studies, there is a tabulation of the base year data described previously. These data are updated under the procedures described for the operations plan. The projected data is generally developed for short-term projections and for the design year. The short-term projection, a 5 to 10 year projection, and the long-term projection is for 15 to 20 years.

Transportation Facilities - Base inventories of the existing highway and transit facility and travel demand are also upgraded annually under the continuing phase of the transportation study. This includes traffic counts on highway facilities, patronage, and revenue data for the transit system, and an update of the inventory of transportation facilities. In addition to this information almost all studies have developed short-term and long-term travel demand. These area travel demands, based on the projected land use and land activity data, are assigned to future transportation networks to provide approximations of the future demand for all major transportation facilities. Data available from these procedures includes zone-to-zone travel demand by trip purpose and mode, total travel demand generated, vehicle miles and vehicle hours of travel by facility type, total travel demand on each segment of the highway and transit system, and travel speed on each segment of the highway network. Travel demand may be defined in subareas, or districts, which are aggregations of traffic zones.

This generalized discussion is intended to serve as a guide to those who may be participating in air quality maintenance planning. It should be recognized that in many urban areas the data required for air quality maintenance planning may not be readily available, or will require reformatting, or even reanalysis. It may be expected that, over time, the 3-C process will include compatible inputs, analyses, and products that can be used for comprehensive environmental planning.

CHAPTER III

AIR QUALITY MAINTENANCE AND COMPREHENSIVE PLANNING

A. GENERAL APPROACH FOR CONSIDERING AIR QUALITY MAINTENANCE IN THE COMPREHENSIVE PLANNING PROCESS

Land use patterns and their attendant activities have a major impact upon the type and amount of air pollution generated over a region. To the extent that land use can be associated with the discharge of pollutants, it is necessary to plan future land use and transportation that is compatible with acceptable levels of air quality. Although comprehensive planning has in the past been relatively insensitive to air quality considerations, it is now incumbent upon the planning community to define and implement the methodology, analytic tools, and standards that will be considered simultaneously with other environmental constraints and directives for planning new development.

In order to accomplish the inclusion of the air quality maintenance segment into the comprehensive plan, two areas must be explored: technical procedures for the incorporation of air quality as a constraint in the planning process and procedures for ensuring or enforcing the maintenance of air quality standards for specific projects. This latter requirement is discussed in the plan preparation guidelines of this series.

B. A PROCESS FOR EVALUATING THE IMPACTS OF LAND USE AND AIR QUALITY PLANS OR POLICIES

In order to consider air quality in the plan development process, some analytical process must be available to define the impact of alternative land use and transportation plans or policy changes on air quality. In addition, the preparation of an air quality maintenance plan requires the analysis of the impact of air pollution control strategies on land use and transportation and its resultant impact on air quality.

One conceptual process for relating land use and/or transportation plans to air quality is described in Figure III-1. This approach is suggested in addition to those discussed in Appendices A and B.* The actual procedure to be applied in any AQMA will depend on the skill and knowledge of personnel, the level of detail of the data base, the funding available to complete the analysis, etc. The procedures used in the four example cities, as discussed in another volume of this EPA guideline series should also be considered.

The suggested process is iterative and could be applied at several points in the development, evaluation, and implementation of air quality maintenance plans as follows:

- Plan Development and Evaluation
    - Evaluation of the air quality or emissions impact of existing land use and transportation plans.
    - Evaluation of the air quality or emissions impact of alternative future land use and transportation plans under different assumptions of control technology or energy needs.
    - Evaluation of the impact of AQMP strategies, Transportation Control Plan (TCP) strategies, and other State Implementation Plan (SIP) strategies on land use and transportation requirements and the resultant air quality impact.
- Plan Implementation
    - Suggest modifications to transportation plans, land use plans, or SIP's at plan update or critical review.
    - Suggest an emissions allocation procedure based upon the estimate of emissions.

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* Environmental Research and Technology, Inc., "A Guide for Considering Air Quality in Urban Planning," (Lexington, Mass.: March 1974).

Figure III-1

THE AIR QUALITY IMPACT-LAND USE PLANNING PROCESS

STEP 1--Establish the Air Quality Baseline

- Existing Concentrations
- Annual Equivalent to Standards

STEP 2--Define the Tolerance of the Planning Area to Additional Pollutant Emissions

- Simplified Dispersion Model

STEP 3--Set Constraints on Industry and Transportation

- Industrial Types and Amount
- Transportation
- Other Environmental Constraints

STEP 4--Generate Comprehensive Land Use Plan

- Major Sources
- Non-Industrial non-transportation land uses

STEP 5--Evaluate Air Quality Impact

- Emissions
- Meteorological Data
- Air Quality Standards

Source: Environmental Research and Technology, Inc., "A Guide for Considering Air Quality in Urban Planning," (Lexington, Mass: March 1974).

The five steps indicated in Figure III-1 are summarized briefly:

Step 1. Establish Air Quality Baseline

The first step is to define existing regional air pollutant concentrations to determine an air quality baseline for the planning area. State air pollution agencies are the primary source for such data. If the existing air quality data is insufficient to represent both the time periods specified in the air quality standards and the spatial distribution of concentrations, additional data should be obtained.

Step 2. Define the Tolerance of the Planning Area to Additional Pollutant Emissions

The allowable increase in air pollutant concentrations should be determined by comparing the air quality baseline to the air quality standards. Allowable concentration increases must then be related to corresponding allowable increases in pollutant emissions. This is accomplished by application of an atmospheric dispersion model. Simplified dispersion models which can be applied are presented in the analysis volume of this Guidelines series.

Step 3. Set Constraints on Industry and Transportation

Based on the tolerance to additional emissions, constraints on the distribution and amount of transportation and industrial sources can be determined. The possible alternatives should be examined against other planning constraints and criteria such as water quality and economic growth at this point. Background information and procedural guidelines for quantifying generalized relationships between industry and transportation and their emissions are presented in the EPA Guidelines series and the ERT document.

Step 4. Generate Comprehensive Land Use Plan

Having defined one or more possible alternatives, the planner must distribute these sources within the planning area. This is accomplished by a detailed, quantified land activity analysis, or by using less sophisticated quantification procedures such as the land use portion of the 3-C plan, or making activity estimates based on a land use map. These are further described in the analysis section of these guidelines. Since this requires the placement of specific land uses within the area, the spatial contours of existing pollutant concentrations as well as the dispersion patterns of anticipated emissions must be considered if local violations of the standards are to be prevented. Generalized dispersion characteristics are presented in the ERT document. In addition, the planner may wish to use a numerical simulation model specific to his planning area. An air pollution specialist would be required to perform such modeling.

Step 5. Evaluate Air Quality Impact

A detailed air quality impact analysis of the comprehensive plan is a final step in the process. This is primarily due to the generalized nature of the data used in the selection process. However, by specifying land uses in Step 4, the planner has generated sufficiently detailed information to perform more extensive analysis.

As described, the land use and transportation plans or policies must provide detailed information relevant to emissions that would result from the plan or policy before it can be translated into the impact on air quality. The following section briefly describes the information required to relate land use to air quality and discusses the availability of techniques to provide this information.

C. INFORMATION AND ORGANIZATION REQUIRED TO RELATE LAND USE TO EMISSIONS AND AIR QUALITY

A generalized flow in information required to relate land use to air quality is given in Figure III-2. As can be seen, the land use or transportation plans do not currently provide the emissions data needed to estimate air quality impact as required by the process shown in Figure III-1. If air quality considerations were a determining factor in the land use planning process, basic emissions data would be collected in conjunction with the basic inventory requirements of a land use or transportation plan.

The content and form of current emissions inventories is mainly a function of modeling requirements. Therefore, one or more intermediate modeling or conversion techniques is needed to translate the land use activity data into the required emissions inventories.

Steps 1 and 2. Generation of Activity Information

The flow diagram indicates that the land use and transportation plan must first be quantified to provide data relevant to the "intensity" of use in the specified land use category. This has been done historically by a combination of economic analyses, surveys (origin-destination studies), and application of activity allocation models. Land activity allocation models have been developed within a wide range of complexity and data base requirements. A brief annotated bibliography of activity allocation models is given in Appendix C to this report. Where such models have been executed, the results can be useful in providing the input necessary for the development of the detailed emissions inventory.

In the Hackensack Meadowlands Air Pollution Study (see Appendix B), estimated emission rates for various land use categories in the areas were developed (see Table III-1). These emission rates are very limited in accuracy because of the limited and generalized land use and activity data upon which they are based. However, they may be useful to planners

FIGURE III-2
INFORMATION ACCESS REQUIREMENTS OF A PROCESS TO
RELATE LAND USE AND TRANSPORTATION PLANS TO AIR QUALITY

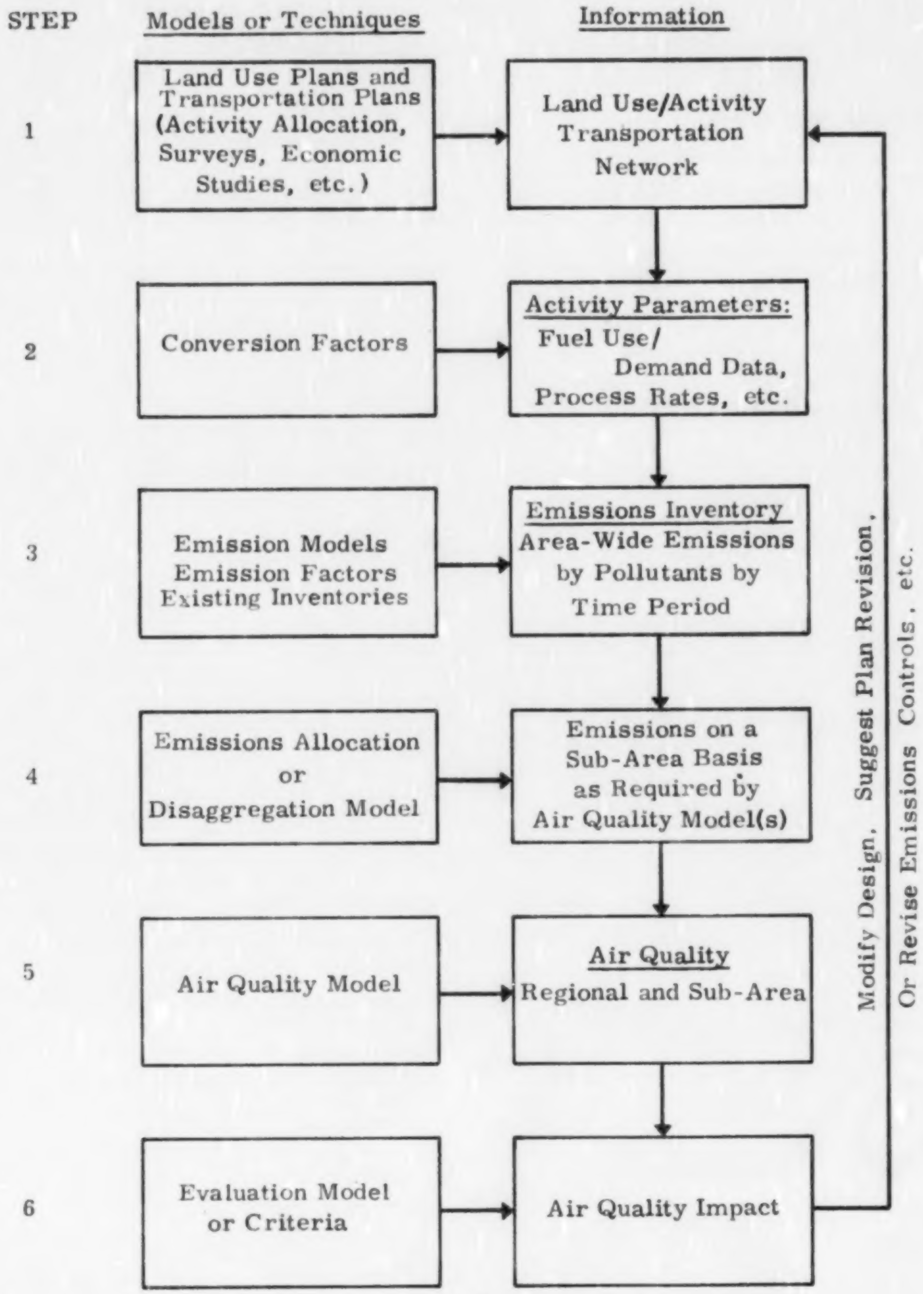
STEP
Models or Techniques
Information
1
Land Use Plans and Transportation Plans (Activity Allocation, Surveys, Economic Studies, etc.)
Land Use/Activity Transportation Network
2
Conversion Factors
Activity Parameters: Fuel Use/ Demand Data, Process Rates, etc.
3
Emission Models Emission Factors Existing Inventories
Emissions Inventory Area-Wide Emissions by Pollutants by Time Period
4
Emissions Allocation or Disaggregation Model
Emissions on a Sub-Area Basis as Required by Air Quality Model(s)
5
Air Quality Model
Air Quality Regional and Sub-Area
6
Evaluation Model or Criteria
Air Quality Impact
Modify Design. Suggest Plan Revision.
Or Revise Emissions Controls, etc.

TABLE III-1

SUMMARY OF ESTIMATED 1990 ANNUAL EMISSION RATES
FOR HACKENSACK MEADOWLANDS LAND USE CATEGORIES

	Pollutant Emissions (lb/year/acre)				
Land Use Category	TSP	SO_2	CO	HC	NO_x
Residential					
10 Dwelling units/acre	25	1	35	12	7
20 Dwelling units/acre	180	120	4	54	85
30 Dwelling units/acre	180	120	4	54	85
50 Dwelling units/acre	250	160	5	75	120
80 Dwelling units/acre	200	140	4	63	100
Commercial & Industrial					
Commercial	60	45	1	12	95
Manufacturing					
Light	1100	1100	10	140	850
Heavy	5400	5400	60	900	5400
Research	2	15	1	5	35
Distribution	60	45	1	12	95
Special Use	60	45	1	12	95
Airport*	100	1000	3000	350	100
Transport Center	180	130	2	36	300
Cultural Center	45	35	1	9	70
Open Space	0	0	0	0	0
Other**	Emission Factors				
Highway (lb/10^6 VMT)	700	400	11000	1000	1500
Parking lots (lb/10^3 hrs idling)	4	4	12	3	1

* Assumes 400,000 flights/year from Teterboro Airport, and 700 acre area.
** Activities are not specified on basis of emissions/unit area.

Source: The Hackensack Meadowlands Air Pollution Study, Summary Report, Environmental Research and Technology, October 1973.

as a rapid evaluation technique for gross planning estimates at the early stages of plan design. This would eliminate the need for Step 2, Conversion Factors. It is recognized that the emission rates in this table are highly specific to the Hackensack planning district, and it would be necessary to create such a table specific to each area of concern. An attempt was made in the "Air Pollution/Land Use Planning Project" (see Appendix B) to prepare such a table which would be generally applicable; however, the results indicate that these factors cannot be generalized. If factors can be developed based on local considerations as in Table III-1, or by similar techniques, the emission factors for the plan area can be developed for each specific pollutant and land use category.

Step 3. Development of Emissions Inventory

The projected regional emissions inventory can be developed at this point from the information generated in Steps 1 and 2. This can be accomplished by applying emissions models to the activity parameters generated in Step 2 or emission factors to the activity categories as shown in Table III-1.

Step 4. Emissions Allocation

In this step the emissions inventory is allocated to a subarea level required to be input to an air quality model. If a quantified land use or activity allocation model has been used to develop emissions in Step 3, the emissions data will already be at a level of spatial distribution sufficient for input to most air quality models.

If, however, the emissions inventory was calculated from regionwide or countywide land use and transportation data the emissions will not be sufficiently disaggregated to support most air quality diffusion models.

Step 5. Air Quality Model

Many air quality models are currently in use in specific areas or studies. These models range from the proportional models such as "roll-back" to highly complex models that are related to fundamental theory. The utility of these air quality models is dependent on the specific application. The guideline document prepared by EPA in this series which discusses air quality models for air quality maintenance plans can be consulted for further information. As the model complexity or level of analysis requirements increase, the concurrent emissions inventory requirements (Step 3) increase.

A rough estimation of the total regional (plan area) air quality impact of the given plan can be made by using a simple proportional model such as "roll-back" to relate emissions to air quality. However, this procedure gives no indication of the resultant spatial distribution of the pollutants within the region (plan area). An air quality planner using a regionwide roll-back technique to evaluate air quality impact of a proposed land use plan could conceivably allocate the pollutant sources in such a manner as to violate the air quality standards within a subareas, although the regional air quality level would still appear to be within the air quality standards. In order to locate and avoid such "hot-spot" problems in the plan, the emissions data must be disaggregated to the level of detail required to identify such problem areas.

If an air quality model is being used to evaluate the effectiveness of a land use control strategy, the data allocation procedure and air quality model used must also be representative of the level of detail required by the strategy definition. For example, a land use strategy that requires control of the location of specific sources would require a site-specific emissions data allocation system.

Ideally, quantified land use should provide the emissions inventory to meet the scale requirements of the air quality model. If such detailed land use and activity data are prepared, Step 4 would become unnecessary.

Step 6. Evaluation

The air quality impact described by the output of the air quality model must be evaluated against the National Ambient Air Quality Standards. Other evaluation criteria might include the exposure of sensitive receptors to pollutant concentrations.

D. ANALYTICAL TECHNIQUES REQUIRED TO RELATE LAND USE AND TRANSPORTATION PLANS TO AIR QUALITY

It is apparent from the previous discussion that a community-specific analytical process must be developed to relate land use or transportation plans to air quality. The process would consist of all the analytical techniques or models required to provide the information needed to relate comprehensive planning decisions to their impact on air quality, and air quality planning decisions to their impact on land use and activity. The process should also provide information and guidance for the planner, local legislative bodies, and the public so that they might clearly perceive the air quality impact of their planning decisions.

The process developed to relate land use to air quality must operate at two levels:

- First, it must be able to relate the impact of the local planning decision on the subarea land use and activity, and resultant air quality.

- Second, it must be able to relate this subarea or project level decision to its impact on the total regionwide (AQMA) air quality.

In addition, the process developed should have the following characteristics:

- It must be specific to the AQMA or planning area in order to fully utilize the information resulting from the 3-C or land use plan.

- It must relate to other planning efforts--environmental, socioeconomic, etc.

- It should provide useful and reliable information to assist in the formulation of policy and administrative guidelines.

- It should provide relevant information on subarea (i.e., county or planning district) issues.

- It should address pollutants of concern.

- It should incorporate unique terrain, and meteorological features, that may affect ambient air quality.

- It should be flexible and be able to incorporate the state-of-the-art in economic projections, land use models, emissions models, air quality models, techniques for quantifying impact, new source control technology, etc.

- It should provide information in a form that can be simply communicated to officials, citizen groups, and other units.

Development of a sound data base and detailed quantification of regional land use and transportation plans should be considered as an integral part of this process development.

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REVIEW OF THE STATE-OF-THE-ART FOR QUANTIFYING THE RELATIONSHIP OF LAND USE AND TRANSPORTATION PLANS TO AIR QUALITY

A. REVIEW OF RELATED STUDIES

If the process for relating land use and transportation plans to air quality is to be used to prepare or evaluate the air quality maintenance plans, all of the techniques and data required to provide the information described in Chapter III must be available and generally applicable. A review of several studies or models that have attempted to relate land use and/or transportation plans to air quality was performed to determine the utility of the study techniques or results to the preparation of air quality maintenance plans.

An analysis of each of the following studies is given in Appendix B of this document. In general, no generally applicable model or technique is available that will meet all of the information requirements discussed below. The models or studies listed below could serve as a core to a community specific process or model. However, all such models require extensive data bases which are not generally available.

1. The Hackensack Meadowlands Air Pollution Study

Developed by Environmental Research and Technology, Inc., this study provides a general methodology for considering air pollution in the formulation and evaluation of alternative urban plans and applies the methodology to alternatives developed for the New Jersey Meadowlands area. The Air Quality for Urban Industrial Planning (AQUIP) model was developed; this model uses a set of submodels requiring detailed data for land use, emission factors, meteorology and ambient air quality.

2. The Air Pollution/Land Use Planning Project

Completed by the Argonne National Laboratory, the objective of this study was to investigate the utility of various land use parameters in describing the air quality impacts of land use plans, using the Chicago region as a test. The tests were made for manufacturing and residential/commercial land uses.

3. Guidelines for Relating Air Pollution Control to Land Use and Transportation Planning in the State of California

These guidelines were developed by the firm of Livingston and Blaney. The purpose was to integrate the goal of achieving and maintaining air quality with the land use and transportation planning process in California metropolitan regions. The primary concept is one of allocating allowable emissions to subareas within air basins.

4. The Transportation and Air Shed Simulation Model (TASSIM)

The study, developed at Harvard University, was designed to develop a model that would integrate existing urban transportation models, vehicle emissions factors, and a simple air diffusion model to analyze air quality effects of various transportation policies. The model was applied and calibrated in the Boston area, using a district level "spider" network, representing the average characteristics of the facilities represented by the network.

5. The Baltimore Regional Environmental Impact Study (BREIS)

An evaluation of the environmental impacts of the proposed urban interstate highway system in the City of Baltimore was the purpose of this study. All environmental analyses, including air quality, were performed on a regional basis. A quantified land use model and travel simulation of seven alternative land use and transportation policies provided the base for examination of impacts. The study was conducted by Alan M. Voorhees and Associates, Inc. for the Interstate Division for Baltimore City.

B. SUMMARY AND CONCLUSIONS

The review of the studies and methodologies listed above, and the techniques described suggest the following conclusions regarding the state-of-the-art in relating land use to air quality and its application to air quality maintenance planning:

1. General Conclusions

a. Land Use Data Base -- Land use can be quantified; however, the available techniques require detailed area-specific data bases.

b. Converting Land Use and Activity Data to Pollutant Emissions -- Procedures do exist for the conversion of detailed land use and activity data to pollutant emissions. However, the procedures are specific to the study area for which they have been generated and the results imply that these procedures would need to be developed on an area-specific basis.

c. Disaggregating Pollutant Emissions Data -- Data allocation procedures do not exist for disaggregating pollutant emissions data. However, the disaggregation of projected (long-term) pollutant emissions is dependent upon detailed land use and activity data that may not be available.

d. Long-Term Air Quality Impact of Land Use -- Mathematical models do exist to relate emissions data to air quality or concentrations. In order to determine the long-term impact of land use on air quality, the procedures referenced in paragraph b above must be available to convert land use data to pollutant emissions data for use in the air quality models.

2. Emissions Calculations

Techniques are available to calculate emissions given detailed process data for each source. Techniques are not readily available or generally applicable for converting land use or activity data directly to the process data necessary for emissions calculations.

3. Emissions Projections

a. Short-term Projection Techniques -- Short-term (1 to 5 years) emissions projections techniques assume little or no change in past trends. Application of any of these techniques requires careful consideration of the assumptions and generalities used to simplify the techniques in order to interpret the results.

b. Long-term Projection Techniques Regional Totals -- Long-term emissions projection techniques are available for projecting regionwide emission totals, given a detailed existing emissions inventory and reasonable regional growth factors. However, existing long-term growth factors are not accurate indicators of the change in emissions and should only be used as "indicators" of a possible problem.

c. Long-term Projection for Transportation Network -- Long-term projection techniques for traffic and transportation network data are available that give the geographic detail necessary to show significant carbon monoxide problem areas within an AQMA due to these mobile sources. However, these techniques are very costly to implement and require detailed data base development that may include land use and activity projections (Land use and activity projection models are referenced in Appendix C).

d. Long-term Projection Techniques for Stationary Sources -- Long-term emissions projection for small areas (sub-county) for stationary sources (other than power plants) is dependent upon detailed knowledge of the future location of specific sources. This specific data is not currently available. Assumptions can be made to estimate the probable location of future stationary sources within the AQMA; however, emissions projections based on these assumptions would not be sufficiently accurate to make subarea planning decisions without careful surveillance and evaluation of these assumptions as new information becomes available. These emissions projections could be used to indicate possible or "most probable" problem areas.

4. Air Quality Diffusion Models

a. Diffusion Models for Projecting Primary Pollutants -- Diffusion models are currently available to project carbon monoxide (CO), total suspended particulates (TSP), and sulfur dioxide (SO_2) for any geographic levels of detail for which emissions data are available. The accuracy of these projections is dependent upon (1) the accuracy of the emissions data, ambient air quality, and meteorological data used to calibrate and validate the given model and (2) the degree to which the area topographic and meteorological characteristics fit the model assumptions.

b. Diffusion Models Unavailable for Secondary Pollutants -- Diffusion models are not currently available to represent the air quality concentrations of any of the secondary pollutants such as reactive hydrocarbons (HC), nitrogen oxides (NO_x) and oxidants (O_x).

The state-of-the-art in emissions projections and air quality projections are summarized in Tables A-1 and A-2, respectively. It is noted that microscale emissions and air quality projection techniques are dependent on the ability to project growth at that level of detail.

TABLE A-1

STATE-OF-THE ART SUMMARY

EMISSIONS PROJECTIONS TECHNIQUES

	Level of Detail or Geographic Scale								
	Microscale			Subarea			AQMA (or regional)		
Pollutant-Source	N	S	L	N	S	L	N	S	L
CO-Mobile	x	x	?	x	x	x	x	x	x
CO-Stationary	x	x	?	x	x	?	x	x	x
HC-Mobile	x	x	?	x	x	x	x	x	x
HC-Stationary	x	?	o	x	x	?	x	x	x
NO_x-Mobile	x	x	?	x	x	?	x	x	x
NO_x-Stationary	x	?	o	x	x	?	x	x	x
TSP-All	x	?	o	x	x	?	x	x	x
SO_2-All	x	?	o	x	x	?	x	x	x

N--Now (1975)

S--Short term (to 1980)

L--Long term (to 1995 or beyond)

o--Not available

?--dependent on detailed data base projection

x--currently available

TABLE A-2

STATE-OF-THE ART SUMMARY

AIR QUALITY PROJECTION TECHNIQUES

	Level of Detail or Geographic Scale								
	Microscale			Subarea			AQMA (or regional)		
Pollutant	N	S	L	N	S	L	N	S	L
CO	X[3]	X[3]	X[3]	X[2]	X[2]	?	X[2]	X[2]	X[2]
HC	0	0	0	0	0	0	X[1]	X[1]	X[1]
NO_x	0	0	0	0	0	0	X[1]	X[1]	X[1]
0_x	0	0	0	0	0	0	X[1]	X[1]	X[1]
TSP	X	X	?	X	X	?	X	X	X
SO_2	X	X	?	X	X	?	X	X	X

[1] Proportional models, i.e., roll back or roll forward

[2] Subarea and microscale models--statistical models (including Gaussian models), climatological models, etc.

[3] Microscale CO--Line source models, etc., dependent on traffic assignment projection data.

N--Now (1975)
S--Short term (to 1980)
L--Long term (to 1995 or beyond)

0--Not now available
?--Dependent on data base availability
X--Currently available

REVIEW OF SELECTED STUDIES
RELATING LAND USE AND TRANSPORTATION
TO AIR QUALITY

I. THE HACKENSACK MEADOWLANDS AIR POLLUTION STUDY -- ENVIRONMENTAL RESEARCH AND TECHNOLOGY, OCTOBER 1973.

A. Study Purpose and Scope

The purpose of this study was (1) to develop a general methodology for considering air pollution in the formulation and evaluation of alternative urban plans; and (2) to apply this methodology to the planning alternatives developed for the New Jersey Hackensack Meadowlands District. In addition, a planning guidelines document was produced to enable urban planners to introduce air pollution considerations into the planning process.

B. Analytic Techniques

The Air Quality for Urban and Industrial Planning (AQUIP) System developed and applied in this study consists of a set of submodels or routines that perform the following tasks:

- Input data descriptive of the land use or transportation plan is prepared.
- These data are converted into pollutant emissions data.
- Mean ambient pollutant concentrations within the area of interest are predicted and displayed.
- The plan, with respect to other plans through analysis of air quality contours and the computation of quantitative measures of impact, is evaluated and ranked.

Utilizing these submodels and techniques, the following can be evaluated: (1) the compliance with ambient air quality standards, (2) the impact of regional air quality levels, (3) the degree of impact on specific receptors or land use categories that are especially sensitive to the effects of pollutants, and (4) an indication of ways to modify the plan(s) to improve air quality.

LANTRAN is the submodel that processes the land-use and transportation data. The data are independent of grid size and land use is allocated by geographic coordinates and land use zones. Activities are designated as point source, line source, or area source generators for input to the dispersion model. Land use activity and intensity data are converted to emissions using a set of conversion factors, emission factors, and activity parameters based on data specific to the Hackensack plan. A set of default parameters was also developed (specific to Hackensack data) for use when data is missing or incomplete. The air quality dispersion model used (MARTIK) to convert these emissions to air quality is a modification of Martin and Tikvart* as used in the Air Quality Display Model (AQDM). The modifications were made to improve accuracy and to treat line sources directly. Approximation techniques were used to save computer time. The SYMAP software is used to display the model output; this displays concentrations as intensity shadings across the area of interest.

The air quality impact subroutine then performs the following comparisons on a pollutant-specific basis based on the output from MARTIK:

- Compare maximum concentrations to ambient air quality standards (AAQS).
- Determine percentage influence of background concentration of total air quality within each plan.

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* D.O. Martin and J.A. Tikvart, "A General Atmospheric Diffusion Model for Estimating the Effects of Air Quality of One or More Sources," APCA paper 68-148, Presented at 61st Annual APCA Meeting, St. Paul, Minnesota, June 1968.

- Determine the "average" regional air quality.
- Determine the "average" exposure of critical receptors and land use categories to pollutant concentrations for the average or worst meteorological conditions.

C. Model Application

The sample analysis was performed for the Hackensack Meadowlands Planning District, a four by eight mile area near the densely developed lower Manhattan area. Four plan alternatives for 1990 were evaluated and ranked. The pollutants evaluated were TSP, SO_2, CO, HC, and NO_x for annual, summer, and winter averages. The analysis was for regional impact only (microscale impacts were beyond the scope). The sample analyses concluded that:

- The background concentration contribution for the Hackensack area was so significant that land use planning on a regional scale would be ineffective for abatement of regional air pollution levels.
- The analysis of impact of alternatives showed significant differences among spatial patterns due to:
  - Percent mix of land use
  - Relative location of land use activities
  - Relative intensity of land use activities

  The observed spatial differences were especially sensitive to the percent mix of manufacturing and transportation related land use.
- Percentage open-space did not have a significant impact on regional air quality.

D. Conclusions and Recommendations

The application results were evaluated and a guidelines document was prepared that can be "generally applied to the land use and transportation planning process for the consideration of air pollution" in ranking alternative plans. The guidelines should be applied to other planning situations only for consideration of regional scale air quality. Detailed analysis would require the application of the complete AQUIP system and the development of the associated detailed data bases.

Some general conclusions resulting from the analysis are:

- It is important to evaluate and rank plans on the basis of pollutant concentration rather than emissions because:
    - Air quality standards are related to concentration levels.
    - Meteorological conditions are critical in determining capacity of a region to assimilate local source emissions (i.e., to determine conditions under which planned land use developments will exceed or comply with AAQS).
    - Meteorology is critical in determining levels of background pollutant concentrations transported into and out of the planning region.
- Regional air quality considerations are good for making broad estimates of the relative air quality impact of alternative plans but, are totally insufficient for the level of detail required to form the basis for evaluating subarea planning alternatives.
- Regional scale air pollution considerations are not applicable to the explanation or solution of microscale problems (i.e., CO over short time periods and small distances is more likely to be determined by localized influence or short-term extremes in meteorological conditions).
- The regional scale air pollution considerations are appropriate within the planning process to improve regionwide air quality and reduce exposure to the general population and high risk groups within the general population to high concentrations.
- If total concentrations do not exceed AAQS and if the variation in total regional impact among plan alternatives is less than 15 percent, the planner can be neutral in the choice of a plan with regard to regional air quality considerations.
- If background air quality concentrations exceed 60-70 percent of total regional concentration, land use planning is not an effective abatement strategy for regional problems.

- Plan design factors having a primary influence on regional air quality concentrations and spatial pattern are:
  - Percent mix of land use (manufacturing and transportation dominate)
  - Location of land use
  - Intensity of land use (clustering)
- Local topographic and meteorological conditions have a major influence on air quality patterns.

The following recommendations for further study were made by ERT based on the results of the study:

- Refine emissions data, especially activity indices and projection indices.
- Develop further default parameters.
- Further calibrate the air quality model (MARTIK). Meteorological effects studies are needed for model validation.
- Develop a software interface between AQUIP and the computerized data base of air pollution agencies.
- Refine "rapid estimation techniques" for evaluation and ranking of plans.
- Extend AQUIP to the microscale.
- Perform sensitivity analysis and development guidelines for impact.
- Examine air quality in relation to other environmental and planning issues, (i.e., water quality, solid waste, cost/benefit, etc.).

E. Data Requirements

To complete the entire AQUIP sequence, detailed land use intensity or activity, emission factors, meteorological and topographic, ambient air quality, and conversion of default parameters are needed. Accuracy is greatly reduced if any of these data are missing.

The initial idea was to develop guidelines for preparing air pollution elements in local general plans. However, this idea was dismissed because of the regional nature of the air pollution problem resulting in several technical and administrative problems. Instead, a combination regional/subarea approach to integrating air quality goals into the planning processes was suggested as a solution.

The process consists of six steps: (1) compiling detailed inventories of air polluting emissions in subareas of air basins, (2) designating maximum emissions allowable in each subarea, (3) projecting subarea emissions likely to be generated by sources indicated in land use and transportation plans for future years, e.g., 1985 and 1995, (4) evaluating and revising the plans so that the maximum emission limits are not exceeded, (5) adopting and implementing the plans, and (6) monitoring public and private development through a refined environmental impact assessment process. The key to the process is the concept of allocating allowable emissions to subareas within air basins. The premise is that the emission limits will be set up so that air quality standards will be met if plans and projects conform to the limits. An appeal process is suggested to allow deviations in those cases where technical information is available to ensure that air quality standards will not be violated.

B. Analytic Techniques

The study recommends the application of several analytic techniques as follows:

1. Land Use Model

This requires at least three sectors of land use--manufacturing, residential, and commercial with land use inventories and projections developed by subarea.

F. Model Calibration

Existing ambient air quality and meteorological data were used to develop simple ratios of existing to projected data to calibrate the model. Where meteorological or topographic conditions vary significantly from the Meadowlands conditions, the model would require extensive recalibration.

G. Model or Study Status

AQUIP is operational for the Hackensack planning region only and is currently operational on the ERT computer only.

H. Applicability to Other Areas

Based on the characteristics of the Hackensack land use plans, the following can be said: (1) some new routines would be required to reflect the appropriate planning assumptions of new planning development. However, the overall AQUIP procedures and subroutines are sufficiently general to be applied wherever cientata are sufficient to operate them, (2) the explicit quantitative results are less generally applicable as they are representative of the meteorology and topography of the Meadowlands. Any variation from these conditions must be considered; and (3) AQUIP can be used as a projection tool as well as a diagnostic tool, (i.e., it can be used to evaluate strategies).

A REPORT ON GUIDELINES FOR RELATING AIR POLLUTION CONTROL TO LAND USE AND TRANSPORTATION PLANNING IN THE STATE OF CALIFORNIA

A. Study Purpose and Scope

The study purpose was to prepare guidelines for integrating the goal of achieving and maintaining air quality with the land use and transportation planning processes in California metropolitan regions.

2. Data Allocation or Disaggregation Technique

This provides for disaggregation of land use data to subarea level for analysis.

3. Previous Emissions Inventories

Existing inventories for counties and air basins are too general for detailed air quality planning; thus, it is suggested that Basin Coordinating Councils compile planning subarea emissions inventories.

4. Emissions Inventory Development

The study suggests that total emissions inventory be composed of three separate inventories: (1) point sources, (2) stationary source area sources, and (3) mobile source area sources.

5. Emissions Model

The emissions model consists of the methodology used in developing the inventory. Future emissions are projected for 1985 and 1995 based on current or modified emission or emission density factors and projections from land use and transportation plans of: (1) either point source emissions or source parameter data, (2) area source acreage by land use category, (3) vehicle-miles traveled.

6. Air Quality Model

No sophisticated validated air quality model is presently available to predict values in California air basins. It is recommended that the initial program use the proportional model or roll-back technique with provisions for deviation from the model where technical information is available to ensure that ambient air quality standards not be exceeded by the proposed deviation.

C. Application

The application is intended for the air basins of the State of California.

D. Study Recommendations/Conclusions

The study recommends a regional/subarea approach to integrating air quality goals into land use and transportation plans, rather than the development of separate air pollution elements to local general plans and regional transportation plans.

The study also recommends emissions allocation as a control method, with provisions for allowing deviations from emissions limits where an adequate case can be made for the deviation not interfering with attainment or maintenance of air quality standards.

It is recommended that stationary sources be separated into high emitters and low emitters, treating the former as point sources, using point source emission factors, and the latter as area sources, using emission density factors. Mobile sources are treated as area sources, but emissions are based on vehicle miles of travel.

More refined models are recommended for predicting air quality as they are calibrated and validated for California. Periodic updating of emission and emission density factors is also recommended.

E. Data Requirements

Land use parameters include acreage, residential density, nature of uses, production level, fuel consumption, location with respect to transport facilities, and other physical and socioeconomic variables. Transportation factors include vehicle miles of travel and speed. Emission requirements include point source emission factors based on process weight, energy consumption, etc. Emission density factors for low emitter stationary sources are also required.

F. Validation or Calibration

The proportional model has so far proven to be as reliable as would be derived from a more complicated method. However, more refined models calibrated or validated for individual air basins in California would be desirable. Currently, research is underway to develop such models in the San Francisco Bay Area, in the South Coast Air Basin, and in San Diego.

G. Model or Study Status

The study presents a set of recommended guidelines, application results have not been published.

H. Applicability to Other Areas

The guidelines recommended are generally applicable to any area.

III. THE TRANSPORTATION AND AIR SHED SIMULATION MODEL (TASSIM) REPORTS, DOT-OS-30099-3 AND DOT-OS-30099-4, MARCH 1974

A. Study Purpose and Scope

The purpose of this study was to develop a model that integrates existing urban transportation models, vehicle emission factors, and a simple air diffusion model to analyze the air quality effects of various transportation policies. The model was calibrated and applied for the Boston area, disaggregated into 122 sub-areas to simulate the air quality effects of various transportation controls, land use controls, and stationary source policies. The model structure and several model applications are described.

B. Analytic Technique

The TASSIM computer technique is composed of three separate programs, each of which has two or more sub-programs.

1. TASAQD Program -- The TASAQD program is a simplified version of the Air Quality Display Model (AQDM) which models air pollutant concentrations in each sub-area resulting from individual large point sources. The basic simplification is the substitution of a single typical stability class.

2. TASSIM Program -- The TASSIM program contains the following seven sub-programs.

- TRGEN - Total person trips are projected to and from each sub-zone. This sub-model uses the trip generation equations and zonal land activity data typical to most urban transportation studies.

- TRIPAL - Zonal productions and attractions developed by TRGEN are used; trip distribution, mode split and network assignment to a composite highway and transit district or "spider" network are performed.

- EMIT - Auto emissions are calculated based on the network assignments and speeds and combined with non-mobile area emissions to produce air quality surfaces for the region. The frequency with which the Federal standards are exceeded in each of the sub-areas is determined. The diffusion model used for mobile and area sources in this sub-program is a Gaussian vertical distribution (Hanna-Grifford model).

- MODSPT - Adopts the mode split models developed in the urban transportation study to the district level composite highway and transit network to produce estimates of transit person and auto trips for various pricing, level of service, and control policies.

- TRPDST - The gravity model is used for person trip zonal distribution to the district level network.

- SKIMT and JAY - Interdistrict impedance is calculated using a modificaton of the "Moore" minimum path model. Highway only and combined highway-transit network inter-district impedances are calculated and used as input to the mode split model.

- DIAL and DIALT - Transit trips are assigned to the transit subnet. A version of the parallel probabilistic assignment algorithm to assign auto person trips to the composite auto-transit network is used.

3. TASMAP Program -- The TASMAP program generates maps portraying the geographical concentrations or concentration changes using the data developed by the diffusion models.

C. Application

The models described above were calibrated for the Boston regional area and applied to test the effect on air quality by (1) reducing vehicular emissions, (2) applying various prohibition and licensing schemes to auto trips, (3) increasing auto occupancy, (4) reducing transit fares, (5) improving performance of highway and/or transit systems, (6) controlling urban development patterns, and (7) reducing stationary source emissions.

The regional and sub-area air quality for 122 sub-regions were evaluated for the total pollutants, TSP, SO_2, CO, HC, and NO_x, and the change in these pollutants with the various policies and system changes listed above.

D. Study Recommendations and Conclusions

The application for the Boston area permitted an analysis of a wide variety of factors that would affect the air quality. The TASSIM model contains sub-models for trip generation, trip distribution mode split, assignment, composite highway and transit network representation, point source emissions, area source emissions and mobile source emissions, as well as a diffusion model. It also provides for analysis at the sub-area level as well as the regional level. Because the model chain contains all sub-models which are executed very economically in sequence, the effect of policy decisions on the entire model chain can be analyzed for a large number of policy considerations at the sub-region as well as the regional level.

Some general conclusions resulting from the analysis are:

- It is important to consider the total effect of localized air quality control policies since an improvement of air quality may occur in one sub-area but may be reduced in other sub-areas.
- Reducing vehicle emissions to the level set forth in the 1970 Clean Air Act is an effective technique for improving air quality in the metropolitan area.
- The spatial distributions of emissions, and not just the metropolitan-wide aggregate of emissions, must be considered in order to effectively evaluate the effects of individual policies or combinations of various policies.

- It is difficult to generalize about the effectiveness of point source controls because the relationship between point source and concentrations vary widely due to the local meteorology, topography, and the location of large point sources.

- An evaluation of the cost and effectiveness of various policies indicate some of the control strategies analyzed produced small improvements in air quality at relatively large cost.

E. Data Requirements

To apply the TASSIM model requires (1) subarea, interarea travel times and trip interchange; (2) inventories of stationary emissions; (3) meteorological parameters; (4) vehicle emission rates; (5) social-economic characteristics of the population for the calibration and application of the trip generation and mode split equations; (6) person trip generation equations (usually developed as part of the transportation planning process); (7) "Gravity Model" trip distribution procedure ("F" and "K" factors developed as part of many of the transportation plans); and (8) "Model Split Model" to be applied to person trips distributed by the gravity model.

F. Calibration

The models for trip generation, trip distribution, and mode split developed as part of the transportation planning process, were used with 1970 census land activity data and employment data, and the forecasted air quality compared favorably to the monitoring data collected in the area. If the trip generation, trip distribution, mode split models, interarea travel times trip interchange, and inventory of stationary sources are available, the model could be calibrated for other metropolitan areas.

G. Model or Study Status

The TASSIM model is operational, and FORTRAN decks of the programs have been executed on an IBM 370/145 and 370/165.

H. Applicability to Other Areas

The TASSIM model is designed to use data and models developed by many of the urban transportation studies. If person-trip generation equations, gravity type distribution models, and post-distribution mode split models are available, the TASSIM model could be calibrated and applied. In some cases substantial modification would be required to the TASSIM model to accommodate the models generated by the transportation study. The model would be applied at a 100 to 200 sub-region area level. These sub-regions would probably be combinations of the 600 to 1000 transportation planning zones to facilitate the model calibration data developed in the transportation study at the zone level.

The model uses a district level spider network in which all highway and transit facilities are represented by direct connection between district centroids. These "links" are encoded with average characteristics of all the transportation facilities they represent. For the mobile source emissions, the number of vehicles assigned to the link and the adjusted speed assigned to the link are used to calculate the emissions of all facilities represented by this link. They are prorated to the two sub-areas connected by the link based on the square root of the area of the sub-regions. With this technique it is difficult to identify the unique characteristics of specific facilities and the effect traffic volume would have on the operating speeds of individual routes.

IV. AIR POLLUTION/LAND USE PLANNING PROJECT, PHASE II, FINAL REPORT, VOLUME II, ARGONNE NATIONAL LABORATORY, CENTER FOR ENVIRONMENTAL STUDIES, MAY 1973.

A. Study Purpose and Scope

The general purpose of the project was to examine relationships between air quality and land use guidance and control practices. The specific objective of the work was to investigate the utility of various land use parameters in describing the air quality impacts of land use plans. The Chicago metropolitan region was used as the test region.

B. Analytic Techniques

The methodology envisioned predicting the air quality impacts of land use plans from various land use parameters, a part of which involved the following:

(1) A land use model was used to forecast growth or change in land use based on rates of change in land use, employment, and productivity for the different kinds of manufacturing land uses, changes in housing stock and population for residential land use, and changes in square footage of floor space for commercial land use.

(2) An emissions model was based on either emission density factors (emissions per acre) or other emission factors to relate emissions to land uses.

(3) An air quality model was used to determine air quality levels in the region, assuming knowledge of quantity of emissions. The air quality model used was the Air Quality Display Model.

The work described examined the feasibility of developing useful emission factors for an emissions model. Only one pollutant particulates, was examined as a test case.

Separate analyses were conducted for manufacturing land use and for residential/commercial land use.

For manufacturing land use, two methods of developing emission factors were tried. The first method was to develop emission density factors. Four sets of emission density factors, based on mean, median, and "best fit" representations of source inventory data were tried. The usefulness of each set of emission density factors was determined by seeing how well the air quality representation obtained using the factors compared to the air quality representation obtained using the point source emissions data.

The second method was to test the feasibility of using some combination of the following parameters--number of employees, process weight, fuel consumption as well as acres of land-to forecast emissions of manufacturing activities. Linear regression was used as a method of analysis. Statistical tests such as correlation coefficients were used to judge usefulness of parameters for prediction.

For residential/commerical land use, the observation was made that for particulates, emissions were a direct function of fuel consumption and therefore, it was sufficient for predicting fuel consumption. The land use parameter used for predicting residential fuel consumption was mean energy use per dwelling unit, by dwelling unit category. Commercial fuel consumption was predicted by considering mean energy use per thousand square feet, by commercial size category. Analysis of variance was used to determine the breakdowns of dwelling unit categories and of significant commercial size categories.

C. Application

The test analyses were performed on data from the Chicago Metropolitan Air Quality Control Region. The primary data sources used were emission inventories collected by the City of Chicago and the State of Illinois Environmental Protection

Agency and land use data on a square-mile basis collected by the Northeastern Illinois Planning Commission.

D. Conclusions

(1) None of the four sets of emission density factors tested predicted air quality deterioration from manufacturing land use sufficiently well. Thus, the emission density concept was rejected.

(2) One of the linear regression models tried to predict manufacturing emissions on the basis of number of employees and acres of land. As these two parameters are easier to predict or more likely to be predicted in most land use planning than the other two parameters being examined, the model was an effort to determine if they were sufficient to predict manufacturing emissions. They were not. The linear regression model based on all four parameters, however, was sufficient. An attempt was also made to see if number of employees and acres of land could be used to determine the other two parameters, process weight and fuel consumption. If the latter two could be determined from the former two, input would then be available for prediction of emissions from the four parameter model. However, the results were inconclusive.

(3) For prediction of residential emissions, the breakdown of dwelling unit categories that was determined significant was between light residential (less than or equal to twenty dwelling units per building) and heavy residential (more than twenty dwelling units per building). For prediction of commercial emissions, the breakdown of commercial size categories that was determined significant was between light commercial (less than or equal to 20,000 square feet per building) and heavy commercial (more than 20,000 square feet per building). Mean energy use per dwelling unit or per thousand square feet were determined for each category and were found useful predictors of emissions.

E.F.G. Data Requirements, Model Calibration, Model or Study Status

The Argonne project terminated before a methodology or model for predicting air quality impacts of land use plans from land use parameters was developed.

H. Applicability to Other Areas

The approach taken by the project is applicable to other areas. However, the specific research results for the emission model cannot be assumed applicable to other areas, as they reflect data specific to the Chicago region.

V. BALTIMORE REGIONAL ENVIRONMENTAL IMPACT STUDY (BREIS) -- ALAN M. VOORHEES AND ASSOCIATES, INC., MARCH 1974.

A. Study Purpose and Scope

The purpose of BREIS was to evaluate the regional environmental impacts of alternative land use and transportation policies in the Baltimore region. Several environmental analyses--air, noise, water, solid waste, socioeconomic, and traffic--were performed for a 1970 base year plus three 1980 alternatives and four 1995 alternatives for the highway system.

B. Analytic Techniques

The Urban Systems (USM) land use model was first used to determine regional development data for each of the alternatives. Next, a series of transportation models was used to determine trip generation, modal split, and traffic assignments for each alternative.

An emissions model was developed to calculate motor vehicle emissions by link and by trip ends (for cold start and hot soak emissions) from the output of the transportation models. Emissions of CO, HC, and NO_x were summed to the regional planning district level and further summarized by county and for the entire study area. Comparison of emissions from different alternatives indicated the effect of the highway system on automotive emissions and the trend in emissions over time (1970, 1980, and 1995).

Emission data for stationary sources and non-automotive mobile sources were obtained from available inventories. These were projected by a two-step procedure. First, controls that would be applied to individual point sources in the future and to area source categories were estimated. Then, the controlled emissions were increased by use of appropriate growth factors from the Urban Systems Model data or U.S. Department of Commerce projections to account for growth. The two partial inventories were combined to show the differences in total emissions by alternative and the contribution of motor vehicle emissions in each case.

C. Model Application

For pollutants other than CO, maximum projected concentrations were simply estimated by proportional reduction with the emissions data. For carbon monoxide, the APRAC-1A urban diffusion model was used to determine maximum CO concentrations for each alternative. Areas of high suspected concentrations were found by using the grid-point version of that model. Then, receptor points were specified in the areas indicated by the grid-point version to have high background levels, and the synoptic version with the street-canyon subroutine was used to estimate maximum 1-hour and 8-hour concentrations alongside the major streets in those areas.

D. Conclusions and Recommendations

The results of this study have been used by Federal agencies to assess the regional impact of alternative land use and transportation policies. Because the traffic data was prepared at link level it has been possible to perform micro level CO analysis as well for assessment of highways at the project level. Further applications will be completed for the efforts of transportation control strategies and energy consumption. The local decisionmakers are utilizing the results to further evaluate alternative policies.

E. Data Requirements

The procedure applied in Baltimore served to update the 3-C transportation plan as well as to provide a regional environmental assessment. Thus, the activity allocation model and the travel simulation models required input data at the zonal level (approximately equal to two to five square miles) as part of the overall process. The air quality and other environmental assessments were conducted at a more aggregate level.

F. Model Calibration

The land use and transportation models were calibrated according to standard practice. The CO model was calibrated on limited receptor sites.

G. Model or Study Status

The BREIS study is essentially complete; however, ongoing analysis will further refine the data and the procedures.

H. Applicability to Other Areas

The approach is readily applicable to those areas that have a quantified land use model and/or a comprehensive update of the transportation modeling process. It can be used to evaluate alternative plans as well as incremental plan changes.

ANNOTATED BIBLIOGRAPHY OF ACTIVITY ALLOCATION PROCEDURES

This technical appendix is intended to inform the reader of some of the activity allocation procedures which have been developed and applied in the United States and elsewhere. The probabalistic models described are the outgrowth of the studies of Ira S. Lowry in Pittsburgh and of A. G. Wilson in England (see Figure of page C-6). Other models, such as EMPIRIC, are econometric-type models.

Batty, Michael. Recent Developments in Land Use Modeling: A Review of British Research. Urban Studies. June 1972.

This paper is primarily a discussion of the development and application of Lowry-type models in England. These models have dominated British research and have been strongly influenced by A.G. Wilson's entropy-maximizing framework. Wilson's framework, which explicitly identifies spatial interaction in terms of stocks and flows of activities, provides a strong theoretical basis for refinements of the original Lowry model. Building on Wilson's work, British researchers have devised several constraint procedures that are consistent with Garin's matrix solution of the Lowry model.

Several Wilson-Garin-Lowry models with constraints have been tested at the subregional and town levels in Britain.

Batty reviews the current research undertaken in England to address the following problems:

- The static equilibrium nature of model projections
- The lack of feedback between the population and service sectors and the basic sector
- The slow convergence of the constraints procedure under model Modification I
- The basic-service definitional problems

- Improved parameter estimation techniques
- The optimum level of aggregation for the model (both in terms of level of analysis and level of data)

Batty concludes that the Wilson-Garin-Lowry formulation is flexible enough to allow for the solution of the above problems and the incorporation of other model refinements as current research introduces them.

Berry, Brian J. L. The Retail Component of the Urban Model. Journal of the American Institute of Planners. May 1965.

The author analyzes work done in Chicago to identify the structure of retail markets in an urban area. He concludes that the correct ecological units for measurement of retail market areas are not transportation zones or census tracts, because they cut across market boundries. Larger analysis units, however, are more likely to capture the effects of the retail business center on its market area. The most useful definition of market area is seen to be the area in which a constant rate of accumulation of trips with distance holds.

The author employs factor analysis to determine the nature of the interdependencies among variables indicative of the size and complexity of the retail centers. Variables tested include functions, establishments, total center area, shopping center area, ground floor area, area of trade area, median income, social class, family class, total competition, planned competition, unplanned competition, ribbon competition, discount competition, and population density.

The results of the factor analysis suggest that the number of functions and their size are highly related to the population of the market area area and the position of the retail centers in a hierarchy. Other independent factors, which are identified by factor analysis, are population of the trade area and the independent variables above are regressed by Berry to produce estimates of retail market area size for planned and unplanned centers.

Chapin, Stuart F., Jr., and Shirley F. Weiss. A Probabilistic Model for Residential Growth. Transportation Research. December 1968.

Chapin and Weiss view urban land development as a dynamic process involving priming actions such as the building of expressways and major industrial parks which promote secondary actions such as the opening of shops or the choice of residential locations. The authors have focused their efforts on the study of residential land use conversion and have determined that the most influential factors in this process are marginal land not in use, accessibility to work, and assessed value.

A Monte Carlo simulation technique (linear form without replacement) is adopted by the authors to distribute the expected level of new housing units to grid cells on the basis of attraction probabilities. Assessed values are used in computing the initial attraction probabilities, while density and housing value constraints are imposed to modify these initial probabilities. Ten density-value classes for subdivided and raw land are considered by the model.

After each simulation period, the attraction probabilities for each grid cell are modified according to anticipated new priming actions and the effects of the land market in the previous development period. The model developed by Chapin and Weiss allocates discrete household units, and the number of these units to be allocated in each simulation period is exogenously specified.

The model is applied to Greensboro, North Carolina, for the years 1948-1960 with three-year simulation periods. The results indicate that the model may be used as a tool for investigating the effect of different land use development policies on residential location patterns. In the future, the authors are hoping to develop submodels which simulate human values and behavior patterns in order to better understand the primary influences on location decisions.

Cripps, E. L. and D. H. S. Foot. A Land Use Model for Subregional Planning. Regional Studies. December 1969.

Wilson's entropy-maximizing approach has been applied in a Lowry-type model to several regions and towns in England. This paper is a full description of the application of such a model to the Bedforshire multimodal subregion.

The model, which strongly resembles the Urban Systems Model, is calibrated and applied in order to allocate population and service employment to 130 zones. Plots of actual and estimated activity are included in the paper as well as statistical indicators of the fit. From the trip tables produced by the model, desire lines of spatial interaction are examined to ensure that trips between selected towns are adequately simulated.

In general, the authors find that the model is able to produce the existing activity structure of the subregion within a reasonable margin of accuracy and that the small-area projections made by the model are sensible. However, the authors note the limitations of the static equilibrium form of the model in describing the process of urban growth and development.

The activity allocation model applied in Bedfordshire has a second shortcoming cited by the authors. The model treats locational factors after the decision to move has been made. The authors contend that there is a need for behavioral submodels which simulate the motivation to move itself. They reveal that such work is already done by A.G. Wilson using the same framework as the Bedfordshire model, and they conclude that such research represents the proper focus for future modeling of locational decisions.

Evaluation of Regional Economic Effects of Alternative Highway Systems. Curtis C. Harris Associates, Inc. FHWA Report, January 1973.

This report summarizes the development and application of a national econometric model which projects population, employment, income, investments, consumption, and government expenditures by 1973 OBE regions. The model contains system sensitive components which may be used to evaluate the effects of alternative transportation systems on regional activity levels. These components are embodied in the transport shadow prices which are derived by solving a linear programming algorithm for each industry.

The transport shipping costs developed by Harris include truck and rail operating costs. The treatment of these costs is of particular interest because the future location of basic employment may be influenced by the level of truck and rail service.

The calculation of rail rates is based on the mark-up of out-of-pocket costs incurred by the carrier. Out-of-pocket costs include terminal and line haul expenses averaged over an extended time period. These costs do not include equipment depreciation rates and overhead expenses. The mark-up factors which reflect revenue to out-of-pocket ratios for each region, are derived from the Annual ICC publication, Procedures for Developing Rail Revenue Contribution by Commodity and Territory.

The methodology for developing truck operation costs which are sensitive to highway system changes relates ICC average operating costs per mile at specific speeds to the TRANSNET network. The ICC operating costs are adjusted to reflect the type of road and terrain and penalties for driving through or around major urban areas. Five highway types are considered.

(1) limited access, divided toll;
(2) limited access, divided free;
(3) other divided;
(4) principal through highways; and
(5) local connectors.

These types are further divided into four speed categories depending upon the terrain.

The speeds associated with the TRANSNET network reflect composite automobile-truck speeds. Therefore, TRANSNET speeds are adjusted to reflect average truck speeds by the following formula:

$$TS = .771S$$

where:

TS = Average truck speed, including stops

S = TRANSNET composite speed

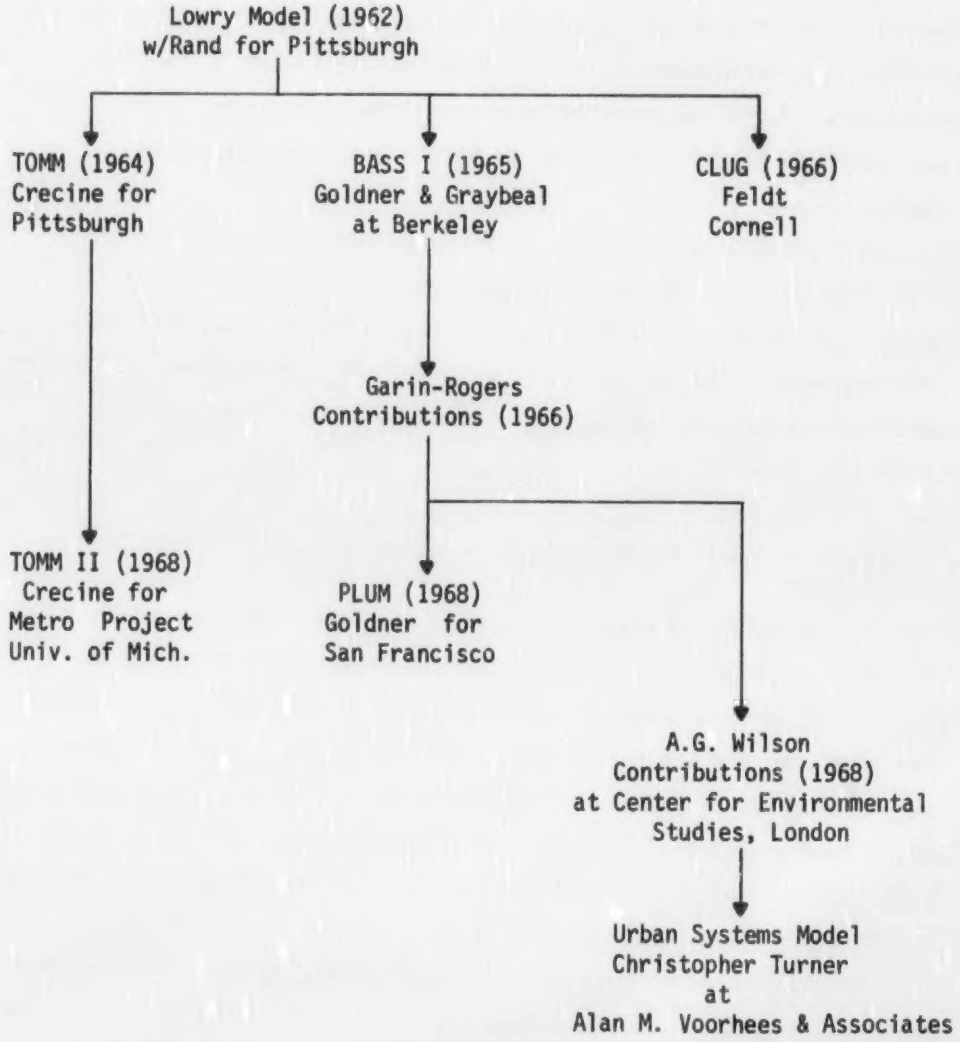
The truck operating cost per vehicle mile is calculated for each state on the basis of the ICC cost-speed data and the TRANSNET link truck speeds. The cost per vehicle-mile is then used in TRANSNET to compute the minimum truck cost path between OBE regions.

In order to account for the friction of traveling through or around urban areas, TRANSNET imposes time penalties, depending on the size of the city. In the Harris study, these penalties are increased by two minutes for truck travel and are converted to costs using the ICC median hourly truck operating costs.

By substituting truck costs for speed and time data in TRANSNET, the Harris study has developed a methodology which is sensitive to the changes in the highway system. For example, truck operating costs may be decreased by the upgrading of a highway or the building of a bypass around an urban area. The major assumption that is made in developing the truck cost methodology is that motor carrier rates will actually adjust to reflect such improvements in the highway system.

Goldner, William. The Lowry Model Heritage. Journal of the American Institute of Planners, March 1971.

This article is a review of the basic Lowry model and its descendants. The structure of Lowry's original model is discussed, and tables of the Pittsburgh calibration parameters, allocation weights, and minimum service employment thresholds are presented. The subsequent theoretical and operational revisions of the Lowry model discussed by Goldner are summarized in the following tree:


Lowry Model (1962)
w/Rand for Pittsburgh
TOMM (1964)
Crecine for
Pittsburgh
BASS I (1965)
Goldner & Graybeal
at Berkeley
CLUG (1966)
Feldt
Cornell
Garin-Rogers
Contributions (1966)
TOMM II (1968)
Crecine for
Metro Project
Univ. of Mich.
PLUM (1968)
Goldner for
San Francisco
A.G. Wilson
Contributions (1968)
at Center for Environmental
Studies, London
Urban Systems Model
Christopher Turner
at
Alan M. Voorhees & Associates

Under the aegis of A. G. Wilson, the Lowry model has been applied at the subregional and town scale throughout England. Empirical work with the model in England has contributed meaningful improvements to the original form.

Goldner maintains that the differences among Lowry-type models are reflected in the following considerations: (1) treatment of the time dimension, (2) degree of disaggregation, (3) handling of development constraints, (4) definition of the areal units, (5) number of variables considered, and (6) calibration and evaluation techniques. Each of the Lowry model descendants are examined with respect to these model considerations.

Goldner concludes that the "promise of meaningful operationality" which characterizes the original Lowry model has inspired a host of variants developed for various planning applications. Although many Lowry descendants in America have failed to reach operationality, British modelers have applied the model at "conceptual, experimental, and operational levels."

Illinois River Basin Pilot Project. Argonne National Laboratory. January 1973.

The socioeconomic/land use mathematical model (SELUM), which was developed in conjunction with the Illinois River Basin project, is similar to the trend analysis technique used in Missouri. The methodology suggested for projection and allocation of state activity levels involves the identification of subregions in the state. These subregions are defined on the basis of activity growth patterns over time, i.e., fast, stagnant, and independent. Trend projections of activity are then made by subregions, counties, and municipalities.

The Illinois activity allocation methodology assumes that the more aggregate projections are most accurate. Therefore, county trend projections are normalized to the appropriate subregional projection, and municipality totals are normalized to the adjusted county projections.

The most attractive feature of this simple state projection and allocation methodology is its flexibility and ease of utility. Data requirements are small. Data for several points in time are the only requirement for the projection of any activity. In addition, the processing of data is greatly facilitated by the package of manipulation and analysis programs developed for the Illinois project.

Kilbridge, M. D., Robert P. O'Block, and Paul V. Teplitz. A Conceptual Framework for Urban Planning Models. Management Science. February 1969.

The authors present a framework for classification of urban planning models which emphasizes the basic characteristics of the model rather than the application. The basic elements which are evaluated for twenty major models are: subject land use, transportation, population, and/or economic activity; function (projection allocation and/or derivation); theory (such as market theory, location theory, and gravity theory); and method (econometric, stochastic, mathematical programming, or simulation.

The authors also address the problems inherent in model building efforts including the lack of adequate data and urban theory to support the construction of models which accurately reflect urban phenomena.

King, Leslie J. Models of Urban Land Use Development. Models of Urban Structure. Lexington, Massachusetts, Lexington Books, 1969.

This paper is a summary of methods for classifying urban development models, as well as an evaluation of the most influential models which have been constructed. The author reviews the model classification schemes suggested by Harris, Kilbridge, et. al, Wilson, and Lowry, and then introduces his own systems analysis framework. This framework involves a ranking of models based on the level of abstraction which characterizes the model. The ranking continuum ranges from empirical observations to simulation techniques to mathematical analyses.

Empirical observations include such "models" as Burgess' concentric zone theory and Hoyt's sector hypothesis. Simulation techniques include both gaming models and Monte Carlo simulations. King describes the most famous urban gaming models, such as CLUG, METRO, and CITY, and summarizes the uses of Monte Carlo techniques in model building. The most abstract technique, that of mathematical analysis, is used in many urban development models, and the author describes the general algorithms of POLIMETRIC, EMPIRIC, and Lowry-type models. Several normative models are discussed, including the Herbert-Stevens linear programming formulation, and significant stochastic approaches are reviewed briefly. The final recommendations of the author are addressed to agencies of small metropolitan areas and these include:

- Delineate specific goals with respect to land use development
- Implement (even a simple linear regression) forecasting model
- Consider participation in an urban simulation game

Model for Allocating Economic Activities into Subareas in a State. Alan M. Voorhees and Associates, Inc. McLean, Virginia. Report for the Connecticut Interregional Planning Program. May 1966.

A differential shift model is developed to allocate manufacturing employment, population, and service employment by type to small areas. The model is a set of simultaneous equations with independent variables which include lagged dependent variables, holding capacities, and accessibilities. The differential shift, which is the dependent variable for each activity type, is added to the proportional share of state growth to determine the net change in small area activity over the forecast interval. The model is applied in distributing activity to 169 Connecticut towns, while a second set of similar models is applied to distribute activity from towns to 804 traffic zones.

Readings in Economic Geography. Smith, Robert H. T., Edward J. Taaffe, and Leslie J. King (eds.). Chicago, Rand-McNally and Company, 1968.

This book is a collection of classical and modern readings in location theory. The sections of most interest with respect to the development of a state activity allocation model involve discussions of central place theory.

In an early section, Brian J. L. Berry and Allan Pred discuss W. Christaller's classical formulation of central place theory. Christaller maintains that regions are characterized by a system of central places whose arrangement is ordered on the basis of three competing principles; namely, marketing, administration, and transportation. Christaller also hypothesizes that the range of a good is determined by the size of the center, the income of the consumer, subjective economic distance and the quantity and price of the good.

John E. Brush presents results of an empirical study of Southwestern Wisconsin which support many tenets of classical central place theory. The settlements or trade centers in the study area are ranked as hamlets, villages, or towns, according to the number of trade functions which they perform and their spatial location. Brush concludes that trade centers in Southwestern Wisconsin are distributed in a radial-circular fashion, supporting the central place hypotheses of Kolb rather than those of Christaller. Brush maintains that trade center hierarchies in America differ from those in Europe and Africa. However, he concludes that it may be possible to formulate hierarchy guidelines which are applicable to similar regions in America.

Two other articles dealing with applications of central place theory are of special interest. A set of general equations is presented by Berry and Barnum to summarize the fundamental characteristics of central places. Specifically, the relationships between the trade area, the population served, and population densities are plotted for four regions. In a second article, Barry, Barnum, and Tennant's application of central place theory to Southwest Iowa suggests that factor analysis is a useful tool for determining the hierarchy of central places.

A Review of Operational Urban Transportation Models. Peat, Marwick, Mitchell, and Company. Final report submitted to FHWA, April 1973.

This document is a summary of operational urban transportation procedures including five major activity allocation models: PLUM, USM, EMPIRIC, Accessibility-Opportunity, and UPM. The comparison of activity allocation models is preceded by a discussion of the appropriate evaluation criteria and these are considered to be: conceptual structure, solution method, policy sensitivity, level of detail, transferability, and man-machine interface. Each of the five models is evaluated with respect to these criteria. The major advantages and disadvantages of each model, as cited in the report, are summarized below.

PLUM or the Projective Land Use Model is a static equilibrium Lowry-type model with a deductive theoretical base. PLUM provides an option for highly disaggregate output (if stratified input data is available) and a land use accounting system is integrated into the structure of the main model. Submodels are also available in the PLUM package for the projection of socioeconomic data. PLUM suffers from the same disadvantages as other Lowry models in that the basic-service employment split is difficult to determine and the model requires exogenous allocation of forecast year basic employment by small areas.

In many respects, the USM or Urban Systems Model is similar to PLUM. It also is a Lowry-type, static equilibrium model, and therefore has a tight, theoretical structure. However, the USM has a simple and more clearly defined calibration process than PLUM due to its repeated application and modification in Britain. The USM does not contain an explicit land use accounting procedure, nor is the current form of the model able to produce disaggregate activity types. The general limitations of Lowry-type models are discussed above. These drawbacks are also applicable to the USM.

EMPIRIC is a completely different type of model from the preceding two. The basic structure of the model is a set of three to 15 simultaneous equations, depending on data availability and desired disaggregation of the output. The dependent variables in these equations represent changes in shares of activities over the forecast interval. The estimation of coefficients for the model variables is a complex procedure which requires a highly trained analyst. However, the package of data manipulation programs which accompanies the basic model facilitates the calibration process. EMPIRIC activity output is generally disaggregated, i.e., population by income group and employment by SIC group, and subordinate models are available for projecting land consumption and socioeconomic variables.

The Opportunity-Accessibility Model has a similar structure to that of the basic modules of PLUM and the USM. The model has been used primarily in allocating trip ends for transportation studies in urban areas. Because of its principal use as an impact analysis tool, its input data requirements are relatively small, and its output is of an aggregated form. Its simplified structure precludes the testing of non-transportation policies, an option which is available within the other four models. Transferability of the model is limited, since it is not actively supported by a staff effort.

The UPM or Urban Performance Model is a time-dependent model with an attractive conceptual structure based on utility theory. The model is principally noted for its use of "opportunity" and "quality" measures which provide a simple and effective framework for the evaluation of urban area projections. Some UPM forecasting options have not been fully tested, however, and the calibration process is not well defined. Therefore, the utility of the UPM in terms of producing urban area projections is as yet unknown.

STAM Socioeconomic and Land Use Data File. West Virginia Department of Highways. March 1972.

West Virginia is developing a comprehensive 1970 socioeconomic and land use data base as part of a Statewide Traffic Assignment Model Study. The socioeconomic variables which are being collected at the 778 zone level can be allocated to the following seven categories: population, auto registration, employment, indices of productivity, education, indices of community structure and accessibility, and recreation of index.

Work sheets and detailed instructions for implementing the data collection process are provided in the West Virginia Manual.

A Summary of the Urban Systems Model. Alan M. Voorhees and Associates, Inc., McLean, Virginia. January 1974.

The Urban Systems Model (USM) is a Lowry-type model which incorporates the entropy-maximizing formulation developed by A. G. Wilson.

The model consists of an integrated set of activity system submodels which distribute population and service employment to small areas in a metropolitan region as a function of: the transportation cost (in terms of time or money) of traveling to the small area; the intrinsic attractiveness of the small area to population or service employment; the competitive attractiveness of all other such small areas; and the activity holding capacity of each small area.

Assuming regional projections of population, primary and service employment, and a small area distribution of primary employment, the USM operates iteratively to distribute increments of employment from work place to residential locations and of service demand from residences and work places to service centers. This iterative procedure converges on the regional population and service employment control totals. After regional convergence is attained and small area holding capacities are satisfied, small area densities, accessibilities, and market potentials are calculated for each activity.

In addition to the calculation of the aforementioned indices, the USM has the optional capbility of calculating the following environmental indices:level of sewer service per resident and per primary employee; level of water service per resident and per primary employee; mobile source emissions (i.e., highway and transit) by district; mobile source air pollution exposure indices (i.e., highway and transit) by district; and noise pollution exposure levels from large stationary sources (e.g., airports) by district.

The USM is a static equilibrium model, which is operated recursively (generally in ten-year periods) to predict activity distributions for future points in time. The temporal dimension is treated implicitly in the model via the usage of logged residential and service employment attraction indices. The model may also be applied in a semi-dynamic form to distribute the growth in activity during the forecast interval.

The USM has been calibrated and applied in the North Central Texas (Dallas-Ft. Worth) and Baltimore regions, is being calibrated for Kalamazoo, Michigan, and is also be adapted for application at the statewide level in Connecticut.

Correlation coefficients (R^2) and root mean square error are calculated by the USM and provide statistical measures of the overall quality of calibration results. The calibration procedure also provides a comparison of the actual and estimated levels of population, service employment, and total employment by small area. Analysis of the North Central Texas calibration results show close correlation between actual and estimated population, service employment, and total employment and a good bit between the actual and estimated distributions of percent work trips against travel cost.

Wilson, A. G. Entropy in Urban and Regional Modeling. London, Pion Limited, 1970.

This reference represents a synthesis of the work done by A.G. Wilson in developing an entropy maximizing approach to spatial interaction within an urban system. Wilson addresses the specific relationship of the entropy-maximizing approach to transport models and locational analyses.

The gravity model, which has usually been derived thorugh analogies with Newtonian mechanics, is derived by Wilson using a statistical approach. The basic gravity model he produces is shown to be applicable in a variety of transport flow situations.

In addition, Wilson demonstrates that the entropy-maximizing approach can be applied to locational models which describe macro-system movements. For example, the location of retail activity and residences may be ascertained via Wilson's approach. However, the author concedes the maximum entropy approach is probably not suitable in projecting discrete industrial locations.

Wilson also discusses the close relationship of the entropy-maximizing approach to input-output economic models and utility-maximizing systems and concludes that the theory is quite adaptable in the field of urban and regional modeling.

Wilson, A. G. Models in Urban Planning: A Synoptic Review of Recent Literature. Urban Studies. November 1968.

The paper presents a systems framework for the design and implementation of planning models. Wilson presents the following hierarchical relevance tree for planning:

Policy

- Action
- Goals
- Evaluation

Design

Plan Formulation
Design Techniques
Problem Formulation

Understanding

Systems Models
Techniques

The author suggests that the most current model building efforts belong to the Understanding stage, but that the future development and application of models should involve both the Design and Policy levels.

Wilson proposes that the following basic questions be addressed during the model development phase:

- What questions is the model trying to answer?
- Which concepts are measurable?
- What variables are at least partially controlled by the planner?
- What level of analysis and disaggregation will be used?
- How will time be treated in the model?
- What behavioral theories will the model represent?
- What techniques are available for implementing the theories?
- What relevant data are available?
- How is model to be calibrated and tested?

Wilson delineates the following urban systems and discusses the most recent modeling work in these areas: spatially aggregated population, spatially aggregated economic, residential, workplace, physical infrastructure, economic activity, transport, and social services.

The remainer of the paper is a review of recent modeling contributions in each of the Policy and Design categories of the planning relevance tree.

Wisconsin Place Classification for Transportation Planning. State of Wisconsin, Department of Transportation, Division of Planning. January 1973.

Wisconsin has developed a framework for ranking activity centers via a composite index of economic importance. Activity centers are classified by the following six identifiers: urbanized area, metropolitan center, regional center, district center, area center, and special center.

The classification procedure is based on the activity center ranking as determined by the following variables: full valuation, sales tax, population, employment, selected services, retail sales, and wholesale trade.

The place classification methodology has been applied in ranking Wisconsin activity centers in 1966 and has been updated for 1970. These rankings have been used in determining the level, location, and type of airports and highways needed in the prime market centers of the state. It is anticipated that the place classification will also be useful in the development of a statewide development and/or land use plan.